ENVIRONMENTAL EFFECTS OF THE OPERATION OF SULPHUR EXTRACTION GAS PLANTS IN ALBERTA

REPORT AND RECOMMENDATIONS

OCTOBER 1972

ENVIRONMENT CONSERVATION AUTHORITY

ALBERTA

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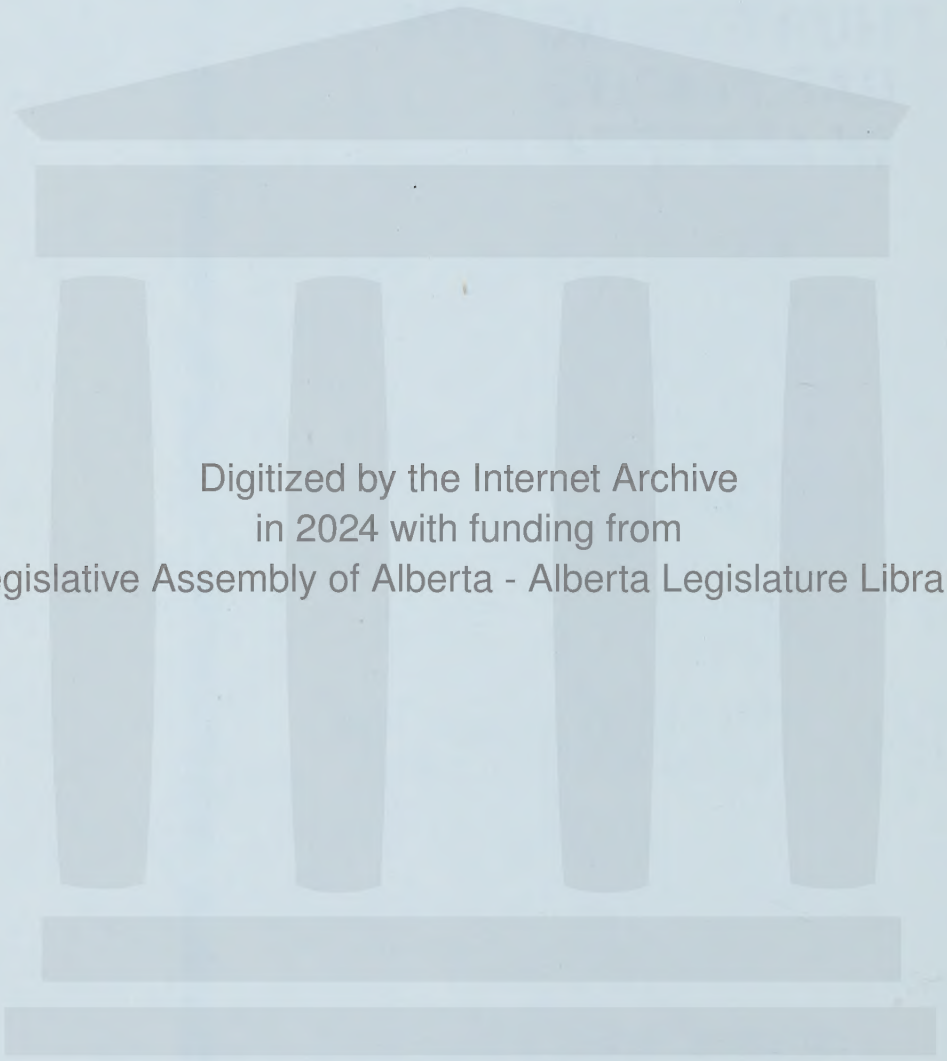

LETTER OF TRANSMITTAL

Lieutenant Governor-in-Council,
Legislative Building,
Edmonton, Alberta.

Honourable W.J. Yurko,
Minister,
Department of the Environment,
Room 207,
Legislative Building,
Edmonton, Alberta.

Dear Sirs:

I have the honour to transmit herewith the Report and Recommendations of the Environment Conservation Authority on the Public Hearings into the Environmental Effects of the Operation of Sulphur Extraction Gas Plants in Alberta, as required by Section 7(1) (e) of the Environment Conservation Act (Chapter 125, R.S.A. 1970 with amendments to June 2, 1972).

I have the honour to be, Sirs, your obedient servant,

W.R. TROST
Chairman
Environment Conservation Authority

WRT/sm

FOREWORD

The land surfaces of the Province of Alberta are varied, richly endowed, and extensively used for agriculture, for forestry, and for recreation, virtually over its entire area. On the other hand, below the surface, and again throughout the Province, seam upon seam of coal is found as well as oil, gas, tar sands, and other minerals. To simultaneously possess valuable though non-renewable resources below the surface and to enjoy abundant ever-renewable surface resources makes the Province twice blessed. At the same time problems can arise when the various surface and subsurface resources are used in ways which are not compatible with each other. An important factor is how these uses and the conflicts between them affect the livelihood and the well-being of the citizens.

The nature of the impact that subsurface resource developments can have on the surface regions depends directly on the nature of the subsurface resources that are being developed. Surface mining to recover coal creates rather a different disturbance than boring a hole to great depth to recover oil or gas but there are other factors to consider. Coal in Alberta possesses rather low sulphur contents which is a distinct advantage. By contrast some of the natural gas deposits in Alberta are highly sulphurous.

Hazards can arise from the release to the surface of these potent gaseous mixtures which may include besides hydrocarbons, compounds like hydrogen sulphide, mercaptans and carbon dioxide intermixed with water which may have salt dissolved in it. Unlike coal which as a solid is easier to contain within a given space, these gases and liquids, once released from their underground confinement, can, unless they are closely managed, become widely dispersed and have profound and widespread effects on the air, the land, the water and on people. For this reason, of course, they are closely managed. The oil and gas industry is a technologically intensive industry in all its aspects. This becomes even more marked

when sulphur is present in natural gas. This element in several of the forms it can assume, is known to have profound effects on living species in both plant and animal kingdoms.

The Environment Conservation Authority had been requested by the Government of Alberta to conduct comprehensive and wide-ranging hearings on the impact on the environment of resource development in Alberta. The Authority has recently completed its Report and Recommendations on the Impact on the Environment of Surface Mining in Alberta and this was tabled in the Legislative Assembly in the fall session of 1972.

In this continuing series of public enquiries, the Authority next directed its attention, at the request of the Honourable Mr. Yurko, the Minister of the Environment, to the environmental effects of the operation of sulphur extraction gas plants. There had been a considerable history of concern amongst citizens as to how their lives and livelihoods were being affected by the operations of the sour gas industry in their immediate neighbourhoods.

As a background to the public hearings, the Authority released its terms of reference, a prospectus on the subject of the hearings and a comprehensive review of the Environmental Effects of the Operation of Sulphur Extraction Gas Plants by Dr. R.F. Klemm.

The Klemm Report brought together all relevant and known information about the operations of sulphur extraction gas plants and the physical and regulatory conditions under which they operate. It analyzed the sources within these plants of possible environmental contaminants, discussed the methods and efficiencies of sulphur removal, and summarized what was known as to the effects of pollutants on air quality and human health, on farm livestock, on vegetation and on soil. The Klemm Report was circulated widely prior to the hearings and became an important basis of information for the public enquiry. Supported by this background work, the Authority then held hearings during October, 1972 in Pincher Creek, Red Deer, Whitecourt, Calgary and Edmonton.

A complete report of all submissions to the hearings, including the Klemm Report, as well as the discussions which followed, is contained in the separate publication entitled "Environmental Effects of the Operation of Sulphur Extraction Gas Plants - Proceedings of the Public Hearings." This publication is in three volumes and is available from the Authority at six dollars per set.

In addition, a summary of the Public Hearings is also separately available and it contains a critique of the hearings by the Science Advisory Committee of the Authority.

The present volume contains the Report and Recommendations of the Environment Conservation Authority on its public enquiry into the Environmental Effects of the Operation of Sulphur Extraction Gas Plants.

DR. W.R. TROST
Chairman
Environment Conservation Authority

ACKNOWLEDGEMENTS

The contribution that a Public Hearing can make to the advancement of any subject depends very largely on the submissions, briefs and presentations made to it by members of the public. The Environment Conservation Authority is very appreciative of the considerable effort of individuals, groups and associations in preparing their submissions to the hearings, and indeed in acting to bring about the hearings themselves.

It is also most helpful and desirable if those who prepare submissions can have ready access to relevant information dealing with the subject under enquiry.

The Authority wishes particularly to acknowledge the invaluable and highly competent contribution made by Dr. Roger Klemm in his report entitled "Environmental Effects of the Operation of Sulphur Extraction Gas Plants", which was widely used by many people before, during and indeed after the hearings. The Environment Conservation Authority is most appreciative of the arrangement entered into by the Research Council of Alberta whereby Dr. Klemm was released from his normal duties to undertake this important project.

To its own staff the Authority expresses a special word of thanks for the many extra hours of effort they contributed to the hearings as well as for their valuable researches, advice and commentaries and for their help in preparing, assembling and producing this and the other post hearing reports.

The Authority also very much appreciates the thorough and thoughtful way in which the submissions were prepared and presented throughout the hearings. There was inevitably a protagonist element associated with the hearings, and in some cases a history of past conflict not yet always resolved in a mutually satisfactory way. The Authority notes the additional element of courage required of an individual who speaks only for himself, and commends those citizens who took upon themselves this lonely and difficult task. The Authority also very much appreciates the thorough, candid and objective way in which the industry analyzed its own operations and attempted to objectively assess the environmental effects of its operations.

Important and in some cases quite original contributions were also made by highly expert individuals either on their own disinterested behalf or as spokesmen for groups or associations. The opportunity to see these different facets of the problem put together under questioning and examination by the Authority so that it made a complete, well-balanced though complex story was a welcome and salutary experience.

Above all, the Authority wishes to commend the citizens of the Province for the direct, honest, effective and reasonable way in which they approach problems that are not simple and involve conflicts between vital and personal interests.

ANNOUNCEMENT

The briefs, submissions and responses to questioning as presented at the hearings are published in a detailed transcript entitled "Proceedings of the Public Hearings on the Environmental Effects of the Operation of Sulphur Extraction Gas Plants". The hearings are also reported in a more concise form in a publication entitled "A Summary of the Public Hearings on the Environmental Effects of the Operation of Sulphur Extraction Gas Plants in Alberta". Both of these volumes are available from the Authority.

TABLE OF CONTENTS

1. SUMMARY

1.1 THE HISTORY OF THE SOUR GAS INDUSTRY IN ALBERTA

It has been known from the very earliest beginnings of the development of the oil and gas industry in Alberta that sulphurous compounds were contained in at least some of the oil and gas deposits of the Province. The sulphur appeared mostly as hydrogen sulphide and separated with the natural gas component making it sour. Initially there was no market for the natural gas whether sweet or sour, and as at Turner Valley the gaseous materials were flared so that the liquid products could be obtained and sold. These were colorful and odoriferous days in the Valley. Further developments established a market for sweet natural gas. Separators to sweeten the gas were set up at the well-site but the sulphurous compounds were still burned and vented to the atmosphere as sulphur dioxide with some hydrogen sulphide still remaining whenever combustion was incomplete. This was in 1933. The years which followed showed little change either in markets or in procedures or new discoveries until 1947. With the sour gas wells at Jumping Pound in 1951 steps were first taken to separate the sulphur as a marketable product. A sulphur recovery unit of 80% efficiency was installed that permitted the recovery of 30 long tons per day of elemental sulphur from a designed maximum input of 35 million cubic feet per day of raw gas.

The completion of pipelines to Eastern Canada and to the United States together with the discovery of additional sour gas reserves enabled a sharp increase in the extraction of sour gas from Alberta fields and in the recovery of sulphur from this product by 1958. These trends continued with the result that sulphur production increased from 45,000 long tons per year in 1957 to 4.5 million tons per year by the end of 1971. From three plants processing natural gas in 1947 the industry has expanded to 152 plants, 67 of which process sour gas now. In the course of these events Alberta has become a major producer of sulphur for the world market.

1.2 SULPHUR RECOVERY

After the first discoveries of oil and gas deposits in Alberta it soon became apparent that more efficient recoveries of these resources could be obtained if improved procedures were adopted. The Oil and Gas Conservation Board, now the Energy Resources Conservation Board, was established jointly funded by industry and by government. Its objectives were to assure that all the oil and gas that could be economically recovered by best procedures was recovered, and that reserves adequate to the needs of the Province for a certain period of time were retained within the Province.

The Board's authority was expanded to include sulphur recovery. With the passage of time and as sulphur-recovery technology improved, the Board steadily set higher percentage sulphur recoveries as guidelines to the sour gas industry. The principle underlying the guidelines was that all the sulphur that could be recovered and sold at a profit should be so recovered. There were at least three interrelated factors. As sulphur extraction technology improved, increased percentage recoveries became possible. As the market for natural gas increased and larger reserves of sour gas were developed increasing tonnages of elementary sulphur were produced for sale on the world markets. The price of sulphur on the world market showed considerable variations and perhaps partly as a result of these factors, fell from a high of $35.53 per ton in 1968 to about $7.50 per ton F.O.B. Alberta in 1971.

The overall trend in sulphur recovery showed a rise from 80% in the initial Jumping Pound Plant up to a range of from 90 to 99% as outlined in the most recent guidelines the Energy Resources Conservation Board has suggested to the operators of gas processing plants. The range covers variations in the size of the plant and the content of sulphur in the sour gas. Companies have been reacting to these new guidelines, in some cases appealing to the Board for exemption from them. An important part of the problem for the gas companies is the rather poor market for sulphur now. It is a poor enough market so that many of the companies

are forced to stockpile a substantial proportion of the sulphur that is recovered. These huge yellow cubes and piles are now becoming a familiar part of the Alberta landscape. Since markets and prices have varied in the past they may again in the future as the most recent trends appear to be indicating.

1.3 ENVIRONMENT CONSERVATION

All of the sulphur that is not recovered is vented to the atmosphere in one form or another but predominantly as sulphur dioxide. In this sense there is a relationship between sulphur recovery and environment protection. There is this sharp difference, however. The problems of sulphur recovery have been approached and tackled in a systematic, methodical and successful way. This has been done by the development of new technology through attention given to it by industry on sound business grounds and by the mandate through legislation of the Oil and Gas Conservation Board to attend to this aspect of resource exploitation.

By contrast initially very little thought was given to legislation concerned with the effects that the sour gas industry might have on other things or living systems outside the plant or in it. The important problem was to get the product out of the ground and to market. Well before a concern about the environment became general, people close to the sulphur extraction plants began to complain about the effects their operation had on them, on their livestock and on their farms. Legal processes were initiated, settlements out of court without prejudice were reached in some cases, and an awareness of a new factor that perhaps needed to be included in the planning of industry began to be discussed. This factor was the impact of their operations on the surrounding environment.

It was, however, only in very recent years that agencies were established by government and regulations laid down that compelled industry to consider the introduction of procedural innovations whose object was environmental protection rather than the profitable recovery and conservation of the mineral resource alone.

In the early years plants were being operated so as to recover the sulphur, but not so as to prevent damage to the environment. However some steps were taken to establish what kind of effects the operation of the sour gas plant might have on the environment. An official investigation into the complaints of individuals as to the effects the sulphur extraction gas plants were having on them was held in 1963. No recommendations for any change in procedure came forth from that Committee. It has only been in quite recent times, since 1970 that a sharp change has come about in the attitude of government and of industry to what could then still be called this new problem.

It is important to distinguish again between sulphur recovery on the one hand and environment conservation on the other. The technology that recovers sulphur is in no way informative about what effect any chemical or ingredient or procedure in the operation of the sour gas industry might have on the living and non-living entities that surround the gas plant. Sulphur recovery is internal to the operation of the plant and is generally based on normal business practice and economic and engineering calculations. The environmental effects of the sour gas industry are external effects, on human beings including the workers in the plant as well as the farmers around it, on other resources and industries, on plants and animals, on soil, air and water, and after-effects of these chemical and biological processes as they exchange, degenerate and finally immerse themselves in the environment at large.

1.4 THE CALL FOR PUBLIC HEARINGS

With the increased importance of the sour gas industry to the Province, as well as the problems that the sulphur presents to the industry and the public alike, it became apparent that new steps had to be taken to examine the question. In the fall of 1971 the Honourable Mr. Yurko, the Minister of the Environment, requested the Environment Conservation Authority to hold comprehensive and wide-ranging hearings into the environmental effects of the operation of sulphur extraction gas plants.

At about the same time the Authority was informed that discussions would soon begin between the Department of the Environment and the Energy Resources Conservation Board in respect of stack emission controls and ambient air quality standards.

1.5 THE MAJOR THEMES

After the preparation and public distribution of a Situation Report on the environmental effects of sulphur extraction gas plants by Dr. Roger Klemm, hearings were held during October, 1972 in Pincher Creek, Calgary, Red Deer, Edmonton and Whitecourt. Though there were common problems, each district also had problems unique to itself so that each hearing developed its own characteristics and structure. A highlight of the hearings was the variety and the quality of the submissions presented by all sectors of the public including the operators of the sulphur extraction gas plants and other members of the oil and gas industry. The operation of sulphur extraction gas plants, and of the sour gas industry altogether, as the gas moves from the underground reserves to the market place, was shown to be highly automated, technologically advanced operation internally. The environmental effects of these operations were also complex and reached the surroundings through many points and in diverse ways, not all of them well known or easily anticipated.

The major themes that developed had to do with the Sulphur Cycle, the control of emissions, social considerations and the verification and assessment of environmental damage. There was implicit agreement on the principle that the polluter should pay; that is, if environmental damage did occur the sulphur extraction gas plants should bear the cost and pass them on to the consumer. There was no agreement as to whether or not environmental damage does occur.

1.5.1 The Sulphur Cycle

The term sulphur cycle was used to describe the transformations

that take place as sulphurous materials are delivered from their deep subsurface storage, processed and finally either sold inside the province, to a consumer outside the province or returned. The sulphurous materials are more conformable with their surroundings at opposite extremes of the cycle, when the material is deeply buried in its underground habitat or is finally absorbed as neutral sulphates in the soil or exported as sulphur to the world market. It has, however, diverse environmental effects in all its intermediate phases. It emerges from the earth as hydrogen sulphide or mercaptans and is oxidized into sulphur dioxide and sulphur trioxide and converted to sulphuric acid, or is reduced to elementary sulphur. Much discussion on the possible effects of these sulphurous compounds and other plant effluents on the health of humans, the health of animals and the health of plants was a highlight of the hearings as was the role that weather and terrain might play in these processes. Finally the natural alkalinity of the soil in the Province tends within certain limits to absorb the sulphuric acid as a neutral sulphate which is either harmless or acts as a fertilizer. A side issue was the possibility that the artificial introduction of sulphur in its various forms might have an indirect effect on animal health through proposed interconnections with a similar chemical, selenium, in such a way as to play a part in the appearance of selenium deficiency diseases in animals.

1.5.2 Control of Emissions

The question under discussion was whether it was adequate to measure the concentrations of the chemicals that could cause harmful effects at the point of contact, namely, ground level, or whether they should be measured and controlled at the point of emission, namely, at the mouth of the stack.

As well, the integrity of the plume, the fate of the plume as it leaves the high stacks or the flare stacks and moves into the atmosphere and outside the bounds of the site attracted a great deal of enlightened analysis. The rate of dilution within it, its control by

inversion, prevailing winds and other climatic events, descriptive terminolo like plummeting plumes, bouncing plumes, and personal reminiscences from people who at ground level had been caught in a plume, contributed to the discussion.

Problems were posed by possible future changes in standards and controls. Another problem was the situation that could arise when additional plants were to be introduced into areas where plants were already functioning both in respect of revised plant operations and the maintenance of ambient air quality standards. The discussion had two sides to it: whether technology existed to meet conceivable future control standards, and then if the technology did exist, could the costs of it be borne by industry?

1.5.3 Social Considerations

A question posed in many ways throughout the Hearings was what society should do if a procedure brings benefit to the large majority but makes an innocent small minority suffer. The analogy here was that the innocent minority were those few people who by accident live and work downwind from the plants and the great majority were the rest of the citizens of Alberta in the cities and the towns as well as in the industry itself who reaped the direct and the indirect benefits of the operation of the sulphur extraction gas plants. Is it a reasonable proposition that the discomfort of some should become a gratuitous contribution to the public good if the public good is indeed served, or should a more detailed analysis of the problem seek a solution more compatible to all concerned.

1.5.4 The Verification and Assessment of Environmental Damage

An important element in the hearings was the announcement of programs conducted by industry into the environmental effects of sulphur ex-

traction gas plants. These were sometimes cooperatively sponsored programs among different companies in a district that had been underway long enough so that some preliminary results could be reported to the hearings. The possibility of citizen participation in these programs, particularly in respect of helping to define the problems that should be researched, and in receiving the reports were significant elements in the discussion. Though there was no agreement as to whether or not environmental damage had occurred most briefs dealt at length with the subject. The two major problems were to prove whether or not damage had occurred and, if it had, to determine to what extent it had produced a disbenefit to another citizen. Some citizens were concerned with other aspects than the cost parameter.

2. DISCUSSION

The development by man of any single resource can often affect his use of other resources. In many cases it might also affect the health or well-being of living species including his own. In the particular case of sour gas extraction the utilization of this resource can by its very nature have diverse effects on other valuable resources and because of the nature of the gases and liquids that are removed from the deep interior of the earth to its surface can have profound effects on living species. The question the hearing addressed itself to was whether the management of these explosive, toxic odorous and unnatural substances was sufficiently meticulous to avoid undue ill effects on living species and on other resources that had value to man.

Throughout the hearings a clear separation in view and in position was evident. Those responsible for the management of the gas resource felt that they had done a good job guarding the public interest, had avoided unnecessary damage to living species, and had also operated without unduly impairing the use of other natural resources including air, water and land. By contrast those who were exposed to the operations of the industry but had gained neither equity nor employment benefit from it commonly and continually repeated an experience in which adverse effects had accumulated to their own health, and to their general environment.

Representations from highly qualified but personally uninvolved individuals added much depth and learning to the exploration of the subject. The main point however, was clear. Sour gases are by their very nature inimical to the health of plants and animals. In extracting them from the earth and processing them, further harmful products are formed. All of these products can be dispersed through the air and collected in the water and in the soil. The question remains as to whether or not management practices have been so good as to prevent ill effects from these activities. There can be no denying that there are potential dangers and potential risks in these operations.

2.1 THE TIME COMPONENT

Another point that needs to be made at once has to do with the passage of time. It has been evident throughout that management practices in the past were not as good as they now are, or perhaps as they will become. Consequently, much of the exchange of views which occurred at the hearings needed to be adjusted for a time component. Evidence was clear that corrosive damage, plant damage and damage to health was much more extensive ten years ago than now. Again the question remained, to what extent is the damage now thought to be occurring identified with the memory of these past experiences?

Associated with that same time concept is the trend in improved management that enabled better protection to be offered to the environment over the past decade, and the question as to whether or not similar improvements can be expected for the future.

2.2 THE PUBLIC ATTITUDE

The general attitude of the public towards any environmental matter is clearly related to its knowledge of the subject. Public awareness of problems associated with the operation of sulphur extraction gas plants may have been increased during the past few years by the publicity generated by citizen complaints in the Pincher Creek area, by reports of the air pollution problems, or by a generally increased concern with environmental quality. Announcements by the Environment Conservation Authority that public hearings would be held on the environmental effects of the operation of sulphur extraction gas plants resulted in immediate public response. Six hundred people attended the public hearings, and a total of 77 submissions were received.

While the substantial attendance at the hearings attested to significant public interest and concern into the operation of sulphur extraction gas plants, the several segments of the news media also gave wide attention to the general aspects of the hearings, as well as to particular briefs

submitted by individuals, organizations, corporations, groups of companies, or representatives of municipal, regional or other levels of government. The many participants placed before the Authority a record which,in extent and technical diversity, had not previously been assembled. The amount and quality of the material placed before the Authority maintained a high standard throughout the hearings. Even the strongest positions taken by citizens generally avoided the posture of direct confrontation, but rather attempted to draw to the attention of the hearings the possibilities which might exist for improvement.

This also applied to the representations which were made on behalf of plant employees concerning conditions within the plant.

2.3 REPRESENTATIONS FROM INDUSTRY

Most of the companies involved in the operation of sulphur extraction gas plants made presentations to the hearings. The submissions were presented by individual companies, by groups of companies, and by the Canadian Petroleum Association. As well, several companies and a group of companies presented reports on research programs dealing with the effects of sulphur dioxide emitted from the gas plants and other environmental effects in areas.

Of particular significance was the brief submitted by the Canadian Petroleum Association, which provided the main focal point for public discussion of the sour gas industry's point of view. In addition, the Association provided a number of consultants, not only to present the brief, but to respond to questioning by the Authority.

Individual operators of sulphur extraction gas plants, as well as companies affiliated with or independent of the Canadian Petroleum Association made specific submissions dealing with particular aspects of their individual operations, as well as adding support generally to the Canadian Petroleum Association brief. However, the material presented by the Canadian Petroleum Association in its brief, constitutes the most definite industry position with respect to the recommendations contained herein. As such, therefore, this brief warrants and has received particular attention to this report.

2.4 SCOPE OF THE HEARINGS

The public hearings on the environmental effects of sour gas plant operations attempted to elicit public discussion on as wide a range as possible of pertinent information. The history of sulphur extraction from natural gas in Alberta spans little more than a decade, and the present scale of operations represents not only the sharply increased demand for natural gas, with attendant favourable scale of production and market economics, but also represent the recent advances in gas treatment technology. In significant measure as well, the level of recovery reflects the conservation policies of the Alberta Energy Resources Conservation Board, and the standards imposed by the Alberta Department of the Environment. The question now is whether anything further needs to be done.

From the earliest installation of sulphur recovery equipment to the present, there has been a notable impact of sulphur production in Alberta on the world supply of elemental sulphur. Increased sulphur production and marketing practices have in the last few years resulted in severe reduction of the price of raw sulphur on the international market. With more stringent sulphur emission standards likely to be imposed by other industrial nations and with the increased use of resources containing sulphur, such as coal, gas and the tar sands, the future market possibilities for elemental sulphur may be subject to fluctuations for several years. This factor was heavily stressed by industry during presentation of briefs and under questioning during the hearings. The necessity for maintaining satisfactory environmental conditions, as well as the economics of sulphur recovery itself will require careful analysis when the economics and technology of present and future gas plant operations are being worked out.

2.5 POLLUTANTS

It is necessary to bear in mind that all of the materials coming out of a sour gas well are toxic, inflammable or in other ways dangerous to the surface environment.

In the processing of sour natural gases, very large columns of gaseous effluents are discharged from the incinerator stacks of sulphur recovery plants. As well, in the field sour gas leaks can occur from formations, wellheads or transmission pipelines. Wellhead flares, emergency flares in the plants, heat and steam, vapours and odors constitute a heavy potential for air borne pollutants. In addition to gaseous effluents, liquids or solids used or produced, either as waste or recoverable as saleable products of the operation of sulphur recovery plants can become effluents. The position is taken, *a priori*, that the sulphurous contaminants in sulphur extraction plant effluents, either gaseous or aqueous, as well as solid materials, represent the most probable area of recognizable environmental impact. For sour gas plants which do not extract elemental sulphur, but which flare hydrogen sulphide to the atmosphere, same position is considered to apply. Thus, in the discussion which follows in this section, considerably more emphasis is placed on these aspects of sour gas plant operation than on others. A similar emphasis will be found in the chapter containing the recommendations.

2.5.1 Air Pollutants

During the operation of a sour gas plant, submissions showed that all tail gas from the plant is continuously incinerated to convert hydrogen sulphide and other sulphur-bearing components to sulphur dioxide. High temperatures and high velocities are maintained in the incinerator stacks in order to discharge the gaseous effluents to as high an altitude as possible, and effect the maximum dilution before the gases can return to ground level. This principle in the total operation however may not always

result in optimum dispersion of stack effluents, a factor which will be considered in greater detail in a following section. Flare stacks, as differentiated from incinerator stacks are used to combust gases at the wellhead or from plant areas which do not pass them to the incinerator. In flare stacks combustion begins at the stack mouth. Flares can blow out and reignition systems are necessary. Flare stacks are also relatively lower and in some cases located in inaccessible and unattended positions. Their efficiency and reliability is therefore much less than an incinerator stack.

In relatively small gas plants, flares may be the only mechanism used to burn hydrogen sulphide prior to its discharge to the atmosphere. Gases associated with pentanes and higher hydrocarbon chains may also pass to the flare stack. Heat and water vapour, as well as carbon dioxide, and oxides of nitrogen also are discharged under some conditions.

In summary, a variety of gaseous effluents may be identified with sour gas plant operations, but hydrogen sulphide and sulphur dioxide must be considered far more important than any others, the first largely because it is highly toxic, and odorous, the second because of its relatively large volumes, as well as its toxic effects at rather low concentrations. Not only were effluents discussed which were discharged outside the plant to the atmosphere by design, but also those odours and vapours inside the plant, which were unlikely to affect the public at large, but which are of concern to plant workmen because of safety or detrimental effects on the working environment. The question of efficient in-plant monitoring is of obvious concern to plant operating staff, and will be the subject of more specific examination in a following section. Finally, field sour gas leaks either at wellhead or in transmission lines constitute a hazard of long standing, and one which requires close attention. The hearings were designed and carried out in such a fashion as to maximize public discussion of all gaseous effluents having potential for environmental degradation, but most attention centered on hydrogen sulphide and sulphur dioxide as the two most abundant and important gaseous effluents from sour gas plant operations.

2.5.2 Contaminants Other than Air Pollutants

Aside from the very large volumes of gaseous effluents flared or discharged from the stacks of gas plants, the liquids or solids mentioned earlier also have a capacity for environmental pollution which may be relatively less known than that of gaseous effluents, but of considerable importance. These may be considered in two general categories; (1) those emanating from the gas field or untreated gas, either at or near wellhead or in transmission lines and (2) those resulting from the operation of the gas plant itself.

In the field, there may be produced considerable quantities of formation water either fresh or salt. The disposal of such fluids, depending on salinity or the amount of dissolved gases contained in them, may be of concern relative to the protection of surface waters or ground vegetation. Such water may require treatment or re-injection, depending on volume and other factors. In any event effects of formation water on other resources must be a recognized component of the assessment of the environmental impact of gas field operations.

In the gas processing plant, waste water from a variety of sources exists and requires disposition. There may be water from washing-down operations, floor drainage, or boiler waste water. Domestic sewage must be treated separately. All aqueous effluents from plant operation have a potential for environmental contamination which must be considered in any treatment of the general question of the effects of the sour gas industry on its surroundings.

2.6 REGIONAL ASPECTS

Of considerable importance are the environmental impacts of gas plants relative to the regions in which they may be located. Several regional aspects arose during the public hearings which require emphasis in their own rights, such as the character and distribution of the human population, the kinds and extent of vegetal cover, physiography and

climate, general land use in the vicinity of gas plants, as well as the possible impacts on renewable resources such as wildlife and fish.

Much of the gas plant activity is in the foothills of the eastern slopes of the Rocky Mountains, or in outriders of the foothills, such as the Swan Hills. The altitude, vegetal cover, temperature and precipitation patterns of the Pincher Creek area, for instance, bear little resemblance to those at Fox Creek, in the edge of the Swan Hills. As well, the flow of Pacific air over the Rocky Mountains has effects on distribution of elements from the stacks not likely to be closely approximated elsewhere in Alberta. Land use also varies. In the Fox Creek area land use is for petroleum operations, timber harvest, and recreational hunting and fishing, whilst in the Pincher Creek area it is largely for ranching and hunting and fishing.

Because of the wide variety in ambient conditions, as well as sharply delineated differences in human habitation, the regional and local environmental impacts must be considered in detail according to information available for specific areas. It would be a mistake to attempt to apply conclusions drawn for plume dispersal and air effluent dilution obtained at Fox Creek to a consideration of stack effluent impacts for a plant east of Calgary or near Pincher Creek. It should be emphasized therefore, that consideration has to be given to the importance of regional or local problems in one area, which might not be apparent in another.

2.7 LEGISLATION

The operations of all sour gas treatment facilities in Alberta are carried out under permits issued by the Energy Resources Conservation Board (ERCB). The standards with respect to ambient air quality are established under the Alberta Clean Air Act and the Regulations under that Act, are administered by the Department of the Environment and enforced by the ERCB. Similarly ambient water quality may be prescribed by Regulations made under authority of the Alberta Clean Water Act and aqueous effluent discharge levels enforced by the ERCB. As well, Provincial Board of Health Regulations

may apply in certain instances. Federal Acts, such as the Canada Fisheries Act, The Canada Migratory Birds Act, Canada Water Act, Canada Clean Air Act or other pertinent Federal Acts all are applicable within their terms of reference.

2.7.1 Energy Resources Conservation Board Guidelines

The Energy Resources Conservation Board has an established policy that sulphur is a valuable natural resource that should not be wasted. In November, 1971, the Board issued a set of guidelines (No. IL 71-29) which indicated that earlier (July, 1970) attention had been directed toward a consideration that sulphur recovery efficiencies were to be improved.

It is to be pointed out that the sulphur recovery guidelines were developed on the basis of the Board's understanding of the current stage of technology and with regard to the cost of the facilities required for high sulphur recovery. The guidelines provide for recovery in the range of 90 - 99 percent as a function of plant size and gas quality. They reflect a modest rate of return on the full sulphur recovery operation under current market conditions.

The hearings provided a basis for comment on the guidelines, both for that segment of the natural gas industry dealing with gas of significant sulphur content, and for the public which might be concerned with the quality of the environment in the vicinity of gas plants or gas field operations. The "Minimum Sulphur Efficiency Guidelines" are reproduced on the following page.

2.7.2 Department of the Environment's Proposed Air Management Standards

As mentioned earlier, the Alberta Department of the Environment has the responsiblity to co-ordinate policies and programs relating to environmental matters and to administer the acts under its jurisdiction. The Alberta Clean Air and Clean Water Acts specify that the Minister of

Minimum Sulphur Recovery Efficiency Guidelines

(Inlet rate LT/day)	Process Requirements	Required Recovery Efficiency for Various Acid Gas Qualities		
		Favourable	Average	Unfavourable
1000 to 4000	Stack clean-up required	98-99	98-99	97-99
400 to 1000	Minimal stack clean-up or equivalent process	96-98	95-98	94-97
100 to 400	Minimum of 3-stage Claus plant or equivalent process	94-96	93-95	92-94
10 to 100	Minimum of 2-stage Claus plant or equivalent process	93-94	92-93	90-92

the Environment has the responsibility for setting maximum permissible levels for discharge of pollutants contained in any effluent, or arising from the operation of any facility. Thus the matter of legal requirements as to the discharge of any substances to the environment are specified in regulations passed pursuant to the Clean Air and/or Clean Water Acts.

In December, 1972, the Minister of the Environment for Alberta authorized the release of a document entitled PROPOSED AIR MANAGEMENT STANDARDS (AMBIENT AND SOURCE EMISSIONS) FOR SULPHUR RECOVERY PLANTS. The document referred specifically to the Board Informational Letter (IL 71-29) with respect to total tonnage released as follows: "Total tonnage of sulphur released by existing plants must not exceed that quantity corresponding to the sulphur recovery guidelines as indicated in the Board's IL 71-29 effective December 31, 1974 or sooner." The total tonnage emission from new plants is equivalent to that amount which corresponds to a maximum 1/2 hour sulphur dioxide concentration of 1600 ppm in the stack gases, at a minimum stack gas temperature of 1000° F and an oxygen content between 2.5 and 7.5 percent. However, under no circumstances shall the total tonnage exceed that amount which is dictated by the ERCB sulphur recovery guidelines.

It is important to emphasize that a major shift is proposed in the manner in which control of sulphur emissions may be achieved in the future. In the document released by the Department of the Environment, objectives are to be achieved by direct control of sulphur content in stack gases at the point of emission. Previously, sulphur balance and ground level monitoring provided the evidence for control, but the new regulations, when passed, will require continuous monitoring of conditions in the incinerator stack itself. As well, stack height and temperature of stack gas outlets will provide the means to control dispersion of stack effluents.

The question of monitoring sites to determine the levels of emissions and dispersion in the environment, as well as the ambient effects of gaseous effluents is a matter of continuing and significant importance

to the industry and public alike. The hearings developed a discussion around the theme of emission control and monitoring methods unmatched in intensity and scope by any other single consideration brought before the Authority.

The proposed environmental standards for sour gas processing plants, as outlined in the document released by the Alberta Department of the Environment are reproduced on the following page.

ENVIRONMENTAL STANDARDS FOR GAS PROCESSING PLANTS

1. Ambient Air Quality Standards

The Department of the Environment is proposing the following maximum sulfur dioxide and hydrogen sulfide concentrations as acceptable levels in ambient air quality:

Time Period	Current Level		Proposed Levels	
	ppm	$\mu g/m^3$ (Approx.)	$\mu g/m^3$	ppm (App
Sulfur Dioxide				
1/2 hour	-	-	525	0.20
1 hour	0.30	785	450	0.17
24 hour	0.10	262	150	0.06
1 year	-	-	30	0.01
Hydrogen Sulfide				
1/2 hour	-	-	17	0.012
1 hour	0.03	42	14	0.010
24 hour	0.005	7	4	0.003

3. PUBLIC OPINION SURVEY

As a follow-up to the public hearings on the environmental effects of the operation of sulphur extraction gas plants in Alberta, it was decided t obtain another independent and objective indication of the public view.

To do this the Authority commissioned a local consulting firm to conduct a public opinion poll on a statistically valid sample of the public.

3.1 PURPOSE

The aim of the survey was to obtain opinions representative of the total population of Alberta with regard to their attitude towards the environmental effects arising from the operation of the sour gas processing plants and the laws and regulatory agencies which control the operations of its plants.

3.2 METHODOLOGY

In consultation with the staff of the Authority, the consultant developed a questionnaire which consisted of 14 questions directed towards the various aspects of the subject that had received emphasis at the public hearings.

The survey was conducted by means of telephone interviews and the calls were made during the evenings and on week-ends in order to obtain the most representative sample mix possible.

3.2.1 Sampling Technique

Two distinct samples were taken, one from the total Alberta population and the other from the specific areas where gas plants are located. The respondents for each sample were selected at random from the appropriate telephone directories.

The general Alberta sample consisted of 120 interviews selected by means of a stratified random sampling technique.

By this technique the population was divided into East and West Rural areas containing the census divisions roughly East and West of ALberta Highway 2, and the two major Metropolitan centres of Edmonton and Calgary. Within each area, respondents were selected at random.

The specific area sample consisted of a further 60 interviews taken in 3 separate areas to the Northwest, Southwest and Southeast where there are high concentrations of gas plants. Again random samples were taken in each area according to population.

3.2.2 Questionnaire

The questionnaire was designed so that in all cases there was a multiple choice of answers, designed to elicit opinions on such subjects as:

1. The relative seriousness of various pollution problems in Alberta.
2. The extent to which people recalled the public hearings.
3. The degree of concern if any for pollution from sulphur extraction gas plants.
4. The benefits from natural gas processing plants.
5. The kinds of environmental effects attributed to the gas plants.
6. The feeling towards legislation and towards the enforcement of regulations.

3.3 RESPONSES

Air and water pollution are apparently regarded as the most serious pollution problems in Alberta. Seventy-seven percent of the respondents from the total population said that they regarded air pollution as serious and 74%

also felt this way about water pollution. Pollution from sulphur extraction gas plants was considered to be "very serious" by 70% of those living in the vicinity of the gas plants and by 58% of the province as a whole according to the survey.

The survey also showed that more people regarded revenue to the province and jobs for Albertans as greater benefits of the gas plants than a plentiful supply of cheap gas, and damage to personal health as their most serious disbenefit.

In general, people appeared to identify furnace stacks as the major source of pollution and considered pipeline leaks to be of secondary importance. Among those living within 10 miles of the gas plants, however, flare stacks were more generally considered to be the major source of pollution.

Sixty-six percent of the total population and 83% of those living within 10 miles of a gas plant would like to see stricter standards imposed on gas plant operations. A third of the people regardless of where they lived wanted the stricter standards enforced more strictly, whilst about one-half wished stricter standards enforced with only as much rigor as now used.

Summary tables of these findings are given on the following pages.

Seriousness of Pollution

	Total Alberta Sample			Gas Plant Areas Sample		
	Air Pollution	Water Pollution	Pollution from Gas Plants	Air Pollution	Water Pollution	Pollution from Gas Plants
	%	%	%	%	%	%
Consider Serious	77	74	58	77	65	70
Not Serious	21	23	25	23	27	23
Don't Know	2	3	17	0	8	7

Greatest Benefit of Gas Plants

Sample	Plentiful Cheap Gas	Jobs	Revenue to the Province	Don't Know
Total Alberta Sample	24	33	40	3
Total Gas Plant Areas Sample	27	32	38	3

Source of Gas Plant Pollution

	Plant Furnace Stacks	Flare Stacks	Pipeline Leaks	None of these
Total Alberta Sample	29	16	14	41
Portion of Total Alberta Sample Living within 10 Miles of a Gas Plant	22	33	17	28

Pollution Standards for Gas Plants

	Want Stricter Standards	Maintain Present Standards	Less Strict	Don't Know
Total Alberta Sample	66	32	0	2
within 10 Miles of Plant	83	11	0	6

Enforcement of Regulations

	Stronger Enforcement Including Shutdown of Plants	Carry on as at Present	Allow Exemptions	Don't Know
Total Alberta Sample	38	52	9	1
Living within 10 Miles of a Plant	38	50	6	6
Edmonton	30	50	17	3
Calgary	40	57	3	0

4. RECOMMENDATIONS

The objective assigned the Authority by Government was "through public hearings to enquire into all effects on the environment of the operation of sulphur extraction gas plants in Alberta, and to review all legislation pertaining thereto; and to lay the views presented to the Authority and the Authority's recommendations thereon before the Lieutenant Governor in Council through the Minister of the Environment."

In the following pages the Authority has grouped its recommendations under major headings that include Social Considerations, the Sulphur Cycle, Monitoring and Control, Sour Gas Field Operations, Living Systems, Economic Considerations and the Identification and Assessment of Environmental Damage. In the discussions preceding the recommendations in each of these sections the Authority has assembled and described the arguments that have led to the Authority's recommendations.

4.1 SOCIAL CONSIDERATIONS

In considering the social implications of the sulphur extraction gas plants attention is given to the relationships between people and the gas plants, employment and investments, legal implications and the question of compensation.

4.1.1 People and the Gas Plants

Albertans are proud of their oil and gas industry. They enjoy the material benefits it has given them, and they also take pride in the skill, the ingenuity and the technological triumphs that this sophisticated, aggressive and skill-intensive industry has created in the Province. Albertans are proud of the role they themselves have played in this transformation. We all have taken satisfaction from the sights and sounds and even the smells of the industry.

At the same time there can be no doubt that what comes up out of the ground from a sour gas well contains products that are highly toxic, dangerously inflammable, explosive, and smell to high heaven. There is nothing particularly wrong, indeed there is something sensible, in a kind of consensus in the Province that these less agreeable facts must not be overemphasized. Nevertheless, because the suphurous gases do smell and do have toxic properties for most living species, the attractive and desirable natural settings of farmers and ranchers who have pioneered the foothill countryside may have become less desirable surroundings. To the extent that this has been so there has been an undue burden and disadvantage to some individuals in the Province.

There has in the past been a certain tendency on the part of all of us to ignore the plight of the few who were disadvantaged and instead take pleasure from the achievements of the industry and from the benefits it has given. Indeed even the people who believe they have suffered have still taken pride in what has been done in the Province in the development of this resource. These attitudes are subject to change. The public hearings and the public poll now show that the majority view has become much more sympathetic to the views that a small minority has been expressing over the years.

One feeling that is common to all those who have suffered disadvantage from the development of the sour gas industry in the Province is a sense of unending and profound frustration. They have not been able to get anyone to believe that they actually have a problem, that they actually are smelling bad smells, suffering from the toxic effects of the gases to which they are exposed, and losing many of the values and delights of the life they had had in their scenic settings before the gas plants came.

There is an irony in the situation. We are all of us now more willing to recognize the possibility that a few individuals might have suffered disadvantages. However, conditions have now very markedly improved over what they were in the past. Public sympathy is being won

but only after most of the suffering has been experienced. It is worth noting that the improvement in conditions was brought about because it became technically possible to profitably extract increasing amounts of sulphur from the sour gases. The improvements did not come about because of the plight of the individuals who were being disadvantaged; or if they did, the people were never told so. Frustration therefore still remains among them and a belief that their rights as citizens are being ignored. This is especially the case among those who believe they are still being exposed to unsatisfactory conditions.

Though the attitudes of the rest of us to the predicament of these individuals in the past is perhaps understandable and certainly is not unusual among human beings, it nevertheless is far from the way that we would like to be treated ourselves. It is in some ways unseemly to separate particular elements among our citizens and point a finger at them more than at others for what was a quite general reaction. However, personnel in industry and above all in the departments and agencies of government have particular responsibilities in these matters.

There is evidence that employees in agencies and departments of government have in the past been less hospitable to the complaints of citizens than they should have been. In the circumstances surrounding the sulphur extraction industry where toxic and dangerous gases are being processed, a private citizen is given inadequate protection by the requirement that he prove beyond a doubt before a court of law that his complaint has its source in the sour gas plant.

The public opinion survey showed that 66% of those interviewed in the general Alberta sample wanted stricter air pollution standards for the sulphur plants and this figure rose to 83% for those living within 10 miles of a gas plant. The Authority therefore feels it appropriate to make four general recommendations. More specific recommendations are made in later sections.

RECOMMENDATIONS

(1) That the fact be accepted that the emanations from sour gas wells and from sulphur extraction gas plants have properties that can be often inimical in well-known ways to the health and well-being of men and other living species, and that the complaints of individuals who have reason to feel they are suffering directly or indirectly from these ill effects be taken seriously until and unless their complaints can be shown to be derived from other sources.

(2) That personnel in industry be encouraged to be attentive to the relevant complaints of citizens in the vicinities of sulphur extraction gas plants and, without prejudice, to adopt the attitude that the citizen's complaint be considered valid unless and until it can be proven otherwise.

(3) That employees in departments and agencies of government be particularly enjoined to adopt the attitude that the complaints of citizens in the vicinities of sulphur extraction gas plants can have validity and that all reasonable steps be taken to assist the citizen in establishing and proving his complaint.

(4) That personnel in industry and in government agencies develop and maintain close liaison with individuals who reside in potential problem areas, such as downwind from gas plants, in order to be aware of the circumstances surrounding complaints, court actions or requests for compensation.

4.1.2 Plant Organization for Environment Protection

There seems to be a close interdependence between three areas of responsibility which must be discharged by plant management. These are:

(i) A determination of the effect on the environment of the plant's operations.

(ii) The question of health hazards and the safety of workers in the plant.

(iii) The problem of training personnel in proper plant operations, particularly those related to the control of environmental risks.

It might well be that these aspects of the overall environmental problem should be handled in a plant in an integrated way, under for example one management person. If they are handled in one division of operations their effective integration might be achieved.

The Authority is informed that at least one company has already taken steps to combine these three responsibilities under one management area.

RECOMMENDATION

(1) That operating companies be required to have educational and training programs in environmental matters, and wherever practical place the responsibilities for measurement of environmental effects, health and safety of plant workers, and the educational and training programs under one management area.

4.1.3 Employment and Investment

The sulphur extraction gas plants represent an important secondary industry, and are a major example in the Province of petroleum products which are fully processed before they are exported. It is therefore a better than usual source of employment and of investment as compared with other productive activities in the industry. These benefits are real.

The processing of its raw materials within the borders of the Province and the further development of secondary industries based on its

natural resources are important and necessary developments in the further evolution of the economy of the Province. Developments such as this are essential if the livelihoods and well-being of the citizens of the Province are to be maintained now and for the future. It is unavoidable that the nature of our society will in part be defined and controlled by the nature of the resources upon which we must subsist and the manner in which they are put to use. It is, however, not unavoidable that the disadvantages of these developments, as well as the safeguards society must erect in the general benefit, should be inequitably distributed among the citizens.

RECOMMENDATION

(1) That the general benefits derived by the Province from the sulfur extraction gas plants as a secondary industry based on the processing of natural resources of the Province and providing employment and investment be recognized and their development encouraged as a normal and desirable part of the industrial development of the Province, but in such a way that their disbenefits do not unnecessarily accumulate on limited groups of citizens or on a few individuals.

4.1.4 Legal Implications

The legal basis for contesting pollution from sulphur extraction gas plants is similar to other legal procedures in that the onus of proof rests with the accusing party. Considerable evidence, however, was presented at the hearings which indicated that citizens are at a distinct disadvantage in proving the cause of debilitation of health or property to the satisfaction of the courts. The technical aspects of environmental investigations require expertise and finances beyond the capability of most private citizens, yet legislation is lacking which provides the public with either investigative or monetary assist-

ance. Without the benefit of relevant and properly analysed factual data citizens' claims may be dismissed as personal evaluations not substantiated by facts.

Even with the above constraints on legal actions citizens have had no option other than the courts for recompense. There have been a number of court cases involving environmental damage claims against sulphur extraction gas plants, including substantial out-of-court settlements without prejudice after examinations for discovery. Such legal confrontations are not conducive to a complete disclosure of facts and information; nor are they likely to result in solutions for the benefit of the general populace, particularly if settlements are made without prejudice out of court but after examination for discovery. Nevertheless, if the rights of individuals are to be adequately protected there must be meaningful legal recourse on matters of environmental pollution. Additional recommendations relevant to this topic will be found in Section 7.8 under the heading Identification and Assessment of Environmental Damage.

RECOMMENDATIONS

(1) That government undertake a comprehensive assessment of the legal and financial constraints on citizens involved in court actions relating to environmental pollution.

(2) That consideration be given to changing the legal code on the basis of the above assessment and an evaluation of the effectiveness of legislation in other provinces and countries.

(3) That environmental impact statements that take into account health and other effects on individuals be required of industry before new sulphur extraction gas plants or major alterations to existing ones are approved.

4.1.5 The Question of Compensation

Over the years the Province has imposed increasingly more restrictive regulations concerning effluents from sulphur extraction gas plants. The result has been a progressive decrease in environmental pollution arising from these operations compared with the situation which existed during the years when the industry was becoming established in the Province.

Although this upgrading of standards was brought about for a number of reasons, there can be doubt that effects on human health and property were effective considerations. While there have been major advances in the application of technology to pollution control there have been virtually no developments with regard to compensation for citizens suffering debilitation from pollution. Since standards and regulations are designed for general application it should be expected that some people living under certain unique environmental conditions might suffer unduly. It seems appropriate that these people should be able to apply for compensation by some means other than the courts.

In addition, in order to bring about a more equitable legal basis for citizen action in the courts existing legislation will have to be changed and new statutes passed. These changes could have serious and wide-ranging consequences and will require preliminary comprehensive study by representatives from all professions and disciplines involved. The public hearings provided an insight into the legal problems as viewed by the citizens, and their concerns may serve as guidelines during consideration of appropriate changes or additional legislation. Following are some general recommendations based on these concerns. Additional recommendations on these matters will be found in section 7.8 under the title The Identification and Assessment of Environmental Damage.

RECOMMENDATIONS

(1) That the government consider the development of statutes which will establish compensatory procedures for citizens who claim and can prove undue hardships from environmental pollution, even though the pollution source may not be exceeding government standards. Some specific recommendations appear in section 4.7.

(2) That consideration be given to the development of legislation outside the courts which would provide for an "examination for discovery" resulting from a citizens' complaint about pollution.

(3) That in the event that the above investigation produces reasonable grounds for complaint, mechanisms for arbitration and appeal be set up by government.

(4) That environmental information and data held in government files be readily accessible to citizens or their legal counsels when contemplating or engaged in arbitration or appeal procedures.

4.2 THE SULPHUR CYCLE

The term sulphur cycle was used to describe the transformations that take place as sulphurous materials are delivered from their deep subsurface storage, processed and finally either sold to a consumer outside the Province or returned to the environment inside the Province. The sulphurous materials are more conformable with their surroundings at opposite extremes of the cycle, when the material is deeply buried in its underground habitat or is finally absorbed as neutral sulphates in the soil or exported as sulphur to the world market. It has, however, diverse environmental effects in all its intermediate phases. It emerges from the earth as hydrogen sulphide or mercaptans and is oxidized into sulphur dioxide and sulphur trioxide and converted to sulphuric acid, or is re-

duced to elementary sulphur. Much discussion on the possible effects of these sulphurous compounds and other plant effluents on the health of humans, the health of animals and the health of plants was a highlight of the hearings as was the role that weather and terrain might play in these processes. Finally the natural alkalinity of the soil in the Province tends within certain limits to absorb the sulphuric acid as a neutral sulphate which is either harmless or acts as a fertilizer.

Unless circumstances arise that upset any of these assumptions, sulphur dioxide emission into the atmosphere from the sulphur extraction gas plants can proceed under reasonable controls. Conditions can arise, however, that disturb the system unfavorably. These occur mostly when the plume is unable to disperse freely in the atmosphere and for one reason or other retains its integrity or is trapped in a situation where dilution does not easily come about. Since the concentration of sulphur dioxide in the stack may be as high as 10,000 parts per million or more depending upon the circumstances of plant operation, while concentrations much above 0.3 parts per million at ground level are thought capable of doing damage to plants and animals even on short exposure, it is evident that a very considerable dilution must occur within the plume as it passes from the stack into the surroundings before it becomes detoxified.

Ideal conditions can and do occur in which the plume would rise straight up into the air, mixing with the gases in the atmosphere, spreading and cooling as it mixes, and then slowly falling downwards because of the greater weight of the sulphur dioxide gases, but spreading over substantial areas. Regions in which there are strong prevailing winds, however, as may occur in mountain valleys, can drive the plume in one direction. It may even be caught up in the funnel of a valley and in this way be trapped or because of its density sink to the lower levels, the bottoms of the valleys or the hollows between hills, and fail to be sufficiently dispersed.

In chinook country, where there are not infrequent strong inversions, the plume may rise to the bottom of the layer of warm air and there spread like a skin of toxic gas, mixing neither with the warm air above nor the cold air below. This is a hazard for birds in flight. The other phenomenon in which the plume retains its integrity may bring the plume sharply down upon the ground. It could then by chance envelop a house or a farmer working in a field and if circumstances have been sufficiently unfavorable, still retain within the plume because of poor mixing higher concentrations of sulphur dioxide than are deemed to be healthful. Such conditions can occur in some of the areas where sulphur extraction gas plants now exist. Many of the claims from individuals as to health damage or to property damage that they had suffered, could be associated with exposure to these kinds of conditions.

The Canadian Petroleum Association brief also recommended that while the present methods for predicting ground level concentrations of sulphur dioxide for specific stack conditions are adequate for relatively flat terrain and normal meteorological conditions, that "more complex analysis of ground level concentration is recommended where unique topographical or meteorological features exist." There is therefore no disagreement that in these particular circumstances additional action is required.

The problems of the flare stacks are somewhat different. Here combustion occurs at the mouth of the stack, and is resorted to for emergency purposes, or because there is no other recourse in the field. Combustion is much less likely to be complete, so that the odours of unburned hydrogen sulphide are commonly associated with flare stacks. The total output of gases from these smaller flare stacks is much less than from the high stacks, but at the same time they are closer to the ground and not well designed for good dispersal. In addition the methods of igniting the flares are in some cases unreliable and the stacks may be in inaccessible locations and not well tended. If the flares blow out then a much richer stream of hydrogen sulphide can be emitted to the atmosphere. The problem from these emergency flare stacks therefore is

more apt to be associated with an emission of hydrogen sulphide and the attendant nuisances and dangers, though under some circumstances, particularly in emergency situations, unduly large concentrations of sulphur dioxide might also present themselves.

Recommendations on the high stacks and the flare stacks are gathered together in section 7.3 under the heading Monitoring and Control. Recommendations relating to Meteorological and Terrain Effects appear in section 7.2.2 under the heading Meteorological and Terrain Effects.

4.2.1 Ambient Air Quality

The background level of sulphur dioxide has been measured in various parts of the world with the values falling in the range of from less than one to approximately five micrograms per cubic meter. This will be the order of magnitude to be expected for a natural background level in Alberta, and can be contrasted to the proposed ambient air quality standards that have been set for this province: 450 micrograms, 150 micrograms, and 30 micrograms sulphur dioxide per cubic meter for 1 hour, 24 hours, and one year respectively. These levels have been set in other countries based on experimental evidence for a lack of damage to human and animal health and to vegetation.

The main form in which sulphur occurs in the atmosphere of the Province as far as concentration is concerned is as sulphur dioxide. Hydrogen sulphide is emitted in small quantities but it is far more toxic and is notorious for its odor. It, however, tends not to accumulate. Its residence time before reacting to form sulphur dioxide or being absorbed by the earth's surface is about one day. This however, does not keep the supply of hydrogen sulphide from being replenished. Sulphur dioxide, on the other hand, may persist for anywhere from twelve hours to about six days, depending upon meteorological conditions. For Alberta, it is expected that in summer the life time for sulphur dioxide will be somewhat shorter since sunlight speeds its oxidation to sulphate, and it is absorbed by soils and vegetation, or comes down in precipitation. In the winter cold

weather will slow down any chemical reaction, and not much is precipitated in snow, therefore a longer time may pass before the sulphur dioxide is removed.

Sulphurous gases have affected living systems in Alberta. Evidence for this was brought forth at the public hearings by individuals whose health had been affected, and by industrial representatives who have examined vegetation in the vicinity of gas plants.

RECOMMENDATIONS

(1) That ambient air quality be maintained at a level which, as far as possible, is consistent with lack of direct effects on humans, or on plants or animals within the area of influence of sulphur plant effluent and that regular review of standards to reflect improvements in knowledge of short- and long-term effects and improvements in technology be carried out. (See also Recommendation 5, section 4.3.2.)

4.2.2 Meteorological and Terrain Effects

During the public hearings, the criteria used and the formulae applied to dispersion of air-borne effluents from the stacks of gas plants were examined. Much discussion centered on the reliability of the application of standard formulae under radically differing conditions of temperature, wind velocity, turbulence, or other factors which could affect plume integrity. It was maintained by some persons that fumigation had occurred at relatively long distances from stacks, and that reliance could not always be placed on the methodology involved in predicting dispersion of effluents, or satisfactory dilution of the contaminants contained therein. Of particular importance in the discussion of plume dispersal were the twin factors of temperature inversion and turbulence which might result in subsidence of gases, resulting respectively in stack effluent containment at relatively low altitude or in "looping plumes" which come to earth relatively intact, and with substantial concentrations of contaminants. In addition, the

special meteorological "chinook" condition so common in south and central Alberta was noted as requiring special attention.

Terrain combines with meteorology to compound some problems. Valleys, mountains, hilly country and hollows can entrap gases of higher density or funnel and channel them in ways that limit their dispersal. These conditions apply to sulphur dioxide which is more than twice as heavy as air and tends to sink below it. Hydrogen sulphide is about 17% heavier than air.

The problem is whether written assurance can be given under different meteorological and terrain conditions that the high sulphur dioxide concentrations in the plume as it leaves the stack (10,000 ppm) can be diluted to the 0.1 ppm thought safe at ground level for several hours exposure.

Computational models can be devised, the hearings were told, that can give detailed relevant information about the dispersion of gases over uneven terrain under varied meteorological conditions.

RECOMMENDATIONS

(1) That the validity of the formulae currently used to calculate dispersal of stack effluents be re-examined under actual conditions as they exist around sour gas plants in Alberta, and that use be made when appropriate, of the recently developed computational models for the dispersion of gases in unique environments.

(2) That the design and location of sour gas treatment plants take into account known or suspected anomalies in meteorological conditions; if meteorological data are not available, they should be obtained before a decision is made regarding the location of a gas processing facility.

(3) That land use and human population distribution in the vicinity of proposed gas processing plants be known in detail and that possible effects weather parameters may have on them be included and applied as criteria used in design and

location of proposed sulphur plants.

(4) That due regard be paid to the extreme variability in weather patterns to be expected annually at any location in Alberta; of special significance should be the attention paid to the frequency and distributional patterns of temperature inversions, particularly in winter.

(5) That suspected or documented cases of fumigation by stack effluents should result in expanded monitoring programs for that area; reported fumigation should result in increased, reliable point sampling monitors.

(6) That whenever possible new plants should be located where problems of terrain and meteorology do not present undue hazards to society.

4.2.3 Water

From briefs submitted, from expression of public concerns and from news media reports, it is apparent that the major emphasis on possible problems associated with gas treatment facilities has largely centered on stack effluents and air-borne contaminants. Notwithstanding the importance of the effects of stack effluents on ambient air quality or human, animal and plant health, water borne contaminants may also be of considerable importance.

Characteristically, aqueous gas plant effluents have tastes and odours associated with sour gas plant operations, may contain oils and greases, or in some cases could contain toxic agents. At natural gas pumping stations particularly, triaryl phosphate, a high quality but extremely toxic lubricant, may pose a threat to safe potability of water or to vertebrate or invertebrate animals living in natural surface waters. In certain cases, water from gas fields may be re-injected into the formation, or toxic substances may be pumped into disposal wells drilled for that purpose, or into available abandoned wells. Whatever the material, or whatever the method of underground disposal, the ultimate fate

of materials disposed of in the earth should be of concern. A general recommendation follows:

RECOMMENDATION

(1) That all materials connected with the operation of sour gas treatment facilities be identified and catalogued as to toxicity or other possible effects on the quality of water into which they might be discharged.

4.2.3.1 Surface Water Quality

Effects of liquid effluents on surface waters are relatively easy to monitor and control. Treatment and final disposition of effluents present modest problems because the volumes are not generally large, but may be difficult because of the kinds of materials involved. Some companies are already following some or all of the following recommendations.

RECOMMENDATIONS

(1) That all liquid effluents be gathered in a common storage facility and subjected to treatment before surface discharge. Such facilities should be protected from humans and from domestic and wild animals through proper fencing.
(2) That discharge of effluent from a treatment facility into a watercourse not be permitted until it is shown that fish (or other bioassay organisms) can live in the undiluted effluent for an appropriate time.
(3) That clarity and odour of effluent from treatment facilities be such that it makes no detectable change in surface receiving waters.

(4) That surface waters in the vicinity of sulphur extraction gas plants be regularly monitored for acidity and for sulphur content.

(5) That when stagnant waters have been adversely affected suitable repair procedures be instituted.

4.2.3.2 Subsurface and Formation Waters

Formation waters may represent quite considerable volumes but the major portion of these can be re-injected into the producing formation at little cost and to the benefit of the well. Data are scanty on quantity and quality, distribution and movement of subsurface waters in Alberta. At present, little is known about the fate of noxious materials injected into the earth. Importance of subsurface waters in the future has yet to be assessed. Thus, the possible future use of subsurface waters must embody strong concerns about materials which may be disposed of beneath the surface of the earth.

RECOMMENDATIONS

(1) That all activities relating to sour gas operations which could affect the quality of subsurface waters be listed on the original application for a permit to operate a gas treatment facility. Such activities should be the subject of a specific review before a licence is issued.

(2) That a record be kept as to kind and quantity of all materials discharged from sour gas fields and treatment plants, if these are to be injected into formations other than those from which they were originally derived.

(3) That water from sour gas formations not be discharged into surface waters unless there is no feasible alternative; and then only after adequate treatment. In general, the principle should be followed that formation water is disposed of by re-injection into the formation of origin.

4.2.4 Soil

Approximately 4.5 million tons of elemental sulphur were produced in 1971 by sulphur recovery facilities in the oil and gas industry in Alberta. At the same time, approximately 550,000 tons of sulphur dioxide along with relatively minor amounts of other sulphurous gases were emitted into the atmosphere, either from incinerator stacks or flare stacks, in field operations, in gas treatment plants, and in refinery operations. As the rate of recovery of petroleum products from the Athabasca oil sands increases, both the production of elemental sulphur and of sulphurous gases will increase. Larger areas of land than at present will be subjected to the influence of sulphur dioxide and other gases, as well as elemental sulphur dust from stockpiling and shipping of sulphur from the various plants.

The effect of sulphur compounds on soils is well known by agriculturists. In general, Alberta soils are sulphur deficient, and raising the sulphate level results in increased capacity for production of vegetation. It would be misleading, however, to suggest that total sulphur emissions from sour gas plants are distributed evenly, or that an average figure can be applied. Thus, considerable caution should be used in making an assessment of the effects of emissions from sulphur recovery plants at any one point in the province until reliable information is available.

To accurately assess the impact of adding air effluents to soils requires detailed study, for the deposition depends upon climatology, meteorology, etc., thereby affecting the amount being added each month and even each year. Of concern to agronomists is the possibility of a gradual increase in soil sulphur to the point where there is essentially an acidification of the soil. The danger of this is not considered to be too imminent however and if it manifests itself in certain restricted areas it can be counteracted effectively by liming which would serve to neutralize the acid and fix the sulphur as calcium sulphate which can be taken up by plants.

Farmers residing near gas plants have been upset about soil deposition of atmospheric emissions, for this represents an uncontrollable

factor in their operations. They have various viewpoints: that gas plants add sufficient sulphur for fertilization; that gas plant emissions cause selenium deficiency diseases in livestock; that the actual amount of sulphur deposited is not known, and therefore there is a question of how much fertilizer to add; and that vegetation is damaged by emissions. To date there has not been a serious investigation of this situation, and such is warranted to properly evaluate the impact of air effluents.

Suggestions as to desirable research and how it might be conducted are to be found under section 4.5.5 entitled Antidotes to Selenium Deficiency Diseases and section 4.5.6 entitled Research Requirements.

4.2.4.1 Effect of Gaseous Effluents

No data appear to exist which give detailed accounts of the possible effects of sulphurous gases on soils. Yet it has been assumed that addition of sulphur to soils is generally beneficial, because most Alberta soils are said to be sulphur deficient.

RECOMMENDATIONS

(1) That a soil survey be designed to catalogue the soil types and sulphur status of soils in the vicinity of sulphur recovery plants.

(2) That the soil survey suggested in (1) be used to provide baseline data for comparison of effects of sulphur on soils generally.

(3) That any change in soil sulphur content be carefully monitored as a safeguard against excessive buildup.

4.2.4.2 Effects of Liquid Effluents

Liquid effluents from sulphur recovery plants such as lubricants, cleaning fluids, catalysts, etc. are generally small in relation to the

volumes of gas handled, or tonnages of elemental sulphur produced. Nevertheless, liquid effluents may contain toxic materials, which require care during disposition. Reference is made to recommendation (1) under section 4.2.3.1 entitled Surface Water Quality. An additional recommendation follows.

RECOMMENDATIONS

(1) That soils in the vicinity of sulphur recovery plants be checked regularly for detection of toxic materials known to exist in liquid effluents.

4.2.4.3 Sulphur Dust

Evidence is available that sulphur dust in the vicinity of sulphur recovery plants may be present in such amounts that soil in the area may be rendered sterile. This comes about by the transformation of sulphur dust to sulphuric acid which, if in sufficient amount, acidifies the soil and prevents growth. Such soil cannot in reasonable time reclaim itself to a productive state, but the addition of lime to it is an accepted reclamation procedure.

RECOMMENDATIONS

(1) That every precaution be taken to ensure that soils are not impaired by sulphur dust spread from sulphur recovery plants as a result of stockpiling, loading for transport or any other operation.
(2) That soils in the vicinity of sulphur recovery facilities be routinely monitored for acidity as well as for sulphur content as an operating requirement of the sour gas industry.
(3) That where soil has been adversely affected by sulphur deposition, suitable reclamation procedures be adopted.

4.2.5 Corrosion

A number of farmers and other residents of the areas surrounding the sulphur extraction gas plants related experiences of severe corrosion damage to their equipment, which they attributed to gas plant emissions. Many of them brought samples of corroded fence wire to the hearings in support of their claims and told also of similar corrosion to agricultural implements, electrical switchgear, and the exterior paint on their houses and farm buildings.

They asserted that these experiences only started after the gas plants came to their area, but as in other cases of alleged damage, they had found it difficult to establish conclusive proof of the cause-effect relationships involved. There have been settlements out of court in the past to cover corrosion costs and some plants now have studies underway to determine if these effects are still occurring and if so, to what extent.

RECOMMENDATIONS

(1) That studies be undertaken by sulphur extraction gas plants to determine corrosive effects of their gaseous emissions on agricultural machinery, fence wire, paints and other farm property in the environs of the plant by the controlled exposure, observation, measurement and analysis of suitable coupons, swatches etc. at varying distances from the gas plants. (See also recommendations in section 4.7.3.2.)

4.2.6 Sulphur Recovery

The method which has been generally adopted by the Alberta gas industry for recovering sulphur is to convert the sulphur compounds in the gas to solid elemental sulphur and to market it in this form around the world.

An alternative which could be significant but which did not receive emphasis at the hearings is to convert either the elemental sulphur or the sulphur dioxide in the flue gases into fertilizers such as ammonium sulphate.

A process for doing this has long been in use as part of Cominco's fertilizer operations at Trail B.C., and it must be assumed that the relevant technology is now fully mature and capable of adaptation to the sour gas industry. In order to convert the naturally occurring hydrogen sulphide in the sour gas to sulphur dioxide, however, some pre-treatment such as a Claus system would be necessary; some flexibility could thus be attained by still allowing a part of the sulphur to be recovered and marketed as elemental sulphur or as sulphuric acid.

In view of the widespread deficiencies of sulphur in Alberta soils and the consequent demand for sulphur-bearing fertilizers it would appear that this method of recovery might offer an alternative to the tail-gas clean-up processes, or even to the Claus recovery process itself, and thus provide an alternate market for sulphur.

RECOMMENDATION

(1) That the economic and technical feasibility of recovering sulphur at the sour gas plants as a sulphate fertilizer either directly or from elemental sulphur, be fully investigated under a wide variety of Alberta conditions, including the tar sands.

4.3 MONITORING AND CONTROL

Among the considerable variety of effluents from sour gas plants that have environmental effects, sulphur dioxide and hydrogen sulphide occupy a special role. Hydrogen sulphide is by far the most important carrier of sulphur in the raw gas, and its controlled combustion produces elemental sulphur which is conserved and sulphur dioxide which

is vented to the atmosphere. The major points at which these gases leave the plant are through the great emission stacks where the conversion to sulphur dioxide of the sulphur contained in any escaping gases is virtually but not necessarily always complete.

In addition throughout the gas plants and in the field there may be emergency flares of much smaller dimensions through which excesses of hydrogen sulphide from normal operations or through plant upsets or other operating irregularities can be burned and vented. Here the conversion to sulphur dioxide might be less complete. In other parts of the operation of the sour gas plant there may be direct leakage of hydrogen sulphide into the atmosphere as for example in poor or corroded fittings at wellheads, or in the cooling of liquid sulphur in which hydrogen sulphide has been dissolve or in plant upsets of one sort or another. Indeed the odor of hydrogen sulphide is a fairly constant component in the environs of the gas plants. However, sulphur dioxide is the principal gas that is discharged into the atmosphere.

To monitor the concentrations of sulphur gases near gas treatment plants is a complex problem. Exposure cylinders have been used to monitor ambient concentrations of hydrogen sulphide and of sulphur dioxide but provide only cumulative measurements. Sulphur dust-fall monitors are also used, but are of value only in the immediate vicinity of sulphur stockpiles. Trailers that contain air monitoring devices are a more recent introduction in sulphur gas monitoring programs. They are equipped to provide continuous measurement of ambient air constituents at any given spot. Although they can be moved from place to place, the trailers require a power source for their operation, and at about $15,000 each, are relatively costly . They can also measure only local conditions, such that ambient air measurements made simultaneously by two trailers even a few hundred feet apart may indicate substantially different results.

4.3.1 Stacks and Flares

Incinerator stacks and flare stacks have been discussed in detail

in the Klemm Report, in the Proceedings and in the Summary of the Public Hearings, and elsewhere in the Report and Recommendations. It is sufficient here to repeat only those aspects that deal directly with the problem at hand.

Though incinerator stacks are by their nature and design better controlled than the emergency flare stacks, plant-based variations do still occur in the concentration of sulphur dioxide in the plume as it passes any specified point in the stack. At the point of emission the concentration of sulphur dioxide may be as high as 5 thousand to 20 thousand parts per million, but also varies from time to time in any specified plant. For different plants the design concentration of sulphur dioxide in the incinerator stacks now ranges from approximately 3,700 parts per million to 16,600 parts per million. Design concentrations do not accurately reflect actual concentrations as stack concentrations are not closely controlled and may vary widely above and below the design concentration.

As the plume leaves the stack dilution occurs due either to mechanical or thermal turbulence. The amount of dilution that takes place before the plume comes into contact with plant or animal life then determines what the sulphur dioxide concentration will be at that time. This dilution factor is also highly variable depending upon atmospheric and terrain conditions. It is variable not only from plant to plant but varies at a particular plant from day to day and even from minute to minute. In addition parts of the plume may become captured in hollows or basins and be less susceptible to further dilution.

Flare stacks differ in function and purpose from incinerator stacks. In the first place they are used for emergency flaring and in the second place combustion takes place at the top of the flare stack rather than at the bottom as it does in the incinerator stack. They are also much smaller. In addition the flare stacks are used much less regularly and are designed to handle situations that are already in many cases dangerous. They must also be brought into action suddenly and without prior warning. The concentration of gases in the plume from the flare stacks is less well known, probably varies more widely and is undoubtedly more complex than that from the incinerator stacks. In general the flare

stacks show the flame whereas the incinerator stacks do not.

Recommendations relating specifically to flares appear in section 4.4.2 under the heading Field Flaring . More general recommendations appear hereunder.

RECOMMENDATIONS

(1) That measurements of ground level concentrations of sulphur gas from sour gas plants be designed in such a manner as to be directly co-related with plant practices and weather conditions.

(2) That effects of ground level concentrations be related to immediate effects, such as noticed by people, as well as to longer term effects on vegetation and animals.

(3) That information be gathered as soon as possible, through appropriate investigations, to develop a total documentation of sulphur emissions, not only for normal plant operations, but also for plant upsets.

4.3.2 Ambient or Ground Level Controls

Regulations as to sulphur dioxide concentration in the past have been based upon permissible concentrations at ground level, where plants and animals would be exposed to it. Monitoring devices set up to measure ground level or ambient concentrations of sulphur dioxide could give either instantaneous concentrations or cumulative concentrations but only at the particular point at which they were located.

An advantage to these standards in principle is that they are based upon concentrations that the animal or green plant is known to be able to tolerate. The disadvantages are that the monitoring devices are limited in number and can only measure concentrations at the points of location. In addition high concentrations are measured only after the damage they cause has been done. The monitors cannot, of course, measure any concentration

whatever in places where they are not located. Moreover, if the case is contested before the courts there is difficulty in providing legal proof as to the source of the sulphur dioxide that the monitor has measured.

4.3.3 Measurement and Control at Point of Emission

There are also advantages and disadvantages to measuring and controlling sulphur dioxide concentration in the incinerator stack itself. For protection at ground level dilution factors will, of course, always have to be relied upon, since technology does not permit the complete removal of sulphur dioxide from the incinerator stack and consequently its concentration in the stack will exceed limits that can be tolerated by plants or animals. The question is, what concentration in the stack is technologically reasonable and, through a safe and reliable dilution factor, can be translated into certainly safe and tolerable levels for plants and animals in the environment.

4.3.3.1 Concentration Control in the Stack

The concentration of sulphur dioxide in the stack can be controlled in a variety of ways. These include the efficiency with which the sulphur is recovered as elementary sulphur and removed from the gas stream in that form. Only the residual sulphur appears as sulphur dioxide. Consequently any increase in the percentage sulphur recovery, if the amount and sulphur content of feed gas do not vary, tends to reduce the sulphur dioxide concentration in the flue gas and hence the amount of sulphur dioxide released to the atmosphere. Tail gas cleanup processes can also be very effective here.

Secondly, the control of the percentage of hydrogen sulphide in the feed gas by suitable adjustments of the mixtures of sweet and sour gases that are fed into the sulphur extraction gas plant or by some other control as to how high a percentage of hydrogen sulphide in a sour gas will be accepted in the gas plant, can also lead to a measure of control of

the concentration of sulphur dioxide in the gaseous effluent from the incinerator stack.

Finally, dilution of the stack gases either by pumping additional air in at the bottom of the stack or by burning additional sweet gas there can reduce the concentration of sulphur dioxide as it leaves the incinerator stack, though obviously, of course, it does not reduce the amount of sulphur dioxide that is discharged.

There are several serious difficulties associated with the dilution method. One of these is the fact that the total amount of sulphur dioxide emitted to the atmosphere is not thereby reduced and indeed by dilution it can even be increased and still meet a fixed concentration guideline. Another difficulty is the mechanical task of diluting by pumping, which is limited in turn by the dimensions of the stacks and therefore may not be fully feasible in old stacks and may need special designs in new stacks. Another difficulty is the requirement that additional sweet gas may have to be burned to heat up the gases to the proper temperature for the processes of dispersion to occur and this is, of course, a waste of a useful resource. It may also be that this device might also require additional pumping which would make further demands on energy resources.

However, when the problems and difficulties associated with controlling the concentrations of sulphur dioxide in the incinerator stack are assessed, it does become clear that methods are available both to measure what the sulphur dioxide concentration in the stack may be and to control it within certain limits. It is to be noted that most gas plants do now measure sulphur dioxide concentrations in the stack even though these concentrations are not themselves closely controlled nor are they used as input to control plant operations.

An important matter for consideration in the future will be total emissions of sulphur dioxide into the atmosphere over Alberta. As the demand for natural gas continues to increase and raw gases containing considerable hydrogen sulphide are processed there is expected to be a corresponding increase in emissions. Tail gas cleanup facilities will provide a brief respite in this upward climb. Every consideration must

therefore be given in the future to assessing the impact of total emissions on air quality. In addition long-range effects must be observed.

4.3.3.2 Control in the Stack versus Control at the Ground

It is suggested that two points are self-evident.

(1) Control of sulphur dioxide concentration as it leaves the gas plant can be most practically and effectively done by measurement and control of the sulphur dioxide concentration in the incinerator stack.

(2) Determination of the environmental effects of the operation of sulphur extraction gas plants, including the effects of sulphur dioxide itself, can best be determined by the reactions of animals and green plants themselves, and by monitoring the air, soil and water that impinge upon the animals and green plants outside the gas plants.

RECOMMENDATIONS

(1) That in order to control emissions of sulphur dioxide and other gases from sulphur extraction gas plants concentrations of gases be monitored both at the point of emission in the incinerator stack and at suitable points at ground level outside the plant. Data should be fed back from both and ground level stations so that actual plant operations can be controlled within prescribed limits.

(2) That permissible concentrations for sulphur dioxide be set in the stack and at ground level so as to adequately protect the health and productivity of people, plants and animals in the environs of the sulphur extraction gas plants.

(3) That additional appropriately detailed calculations be

employed to relate the permissible stack concentrations to the permissible ground level concentrations in areas where meteorology and terrain present particular problems, so as to be sure that in such unusual circumstances no undue damage to the health or productivity of people, plants or animals will ensue.

(4) That improved management procedures be applied to all points where hydrogen sulphide is apt to escape to the atmosphere in order to guard against undue risk from this gas.

(5) That both ambient air quality standards and stack emission concentration standards be reviewed regularly through public hearings and that statutory authority for these regular reviews, perhaps at three-year intervals, be assigned to some body that has environmental responsibilities but has neither administrative nor enforcement responsibilities for the legislation and regulations.

(6) That in attaining permissible stack concentrations of sulphur dioxide, dilution methods which involve the burning of extra quantities of sweet gas be de-emphasized, and that such methods as tail gas cleanup, and appropriate blendings of sweet and sour gas in the feed gas to the plant be preferred methods in controlling sulphur dioxide concentrations in the stack and at the ground level, and that some step wise latitude be allowed so that some immediate improvement may be gained, at the same time allowing operators who are in inflexible circumstances some time to make adjustments. This may be all the more important in cases that are particularly dependent upon terrain and meteorology, where additional data may be needed to determine the appropriate concentrations in the stack.

(7) That in selecting monitoring devices to be employed to detect and warn against environmental damage biological sensors as well as chemical and mechanical sensors should be employed.

(8) That monitoring programs for the estimation of ambient air quality should be designed in such a fashion that comparisons can be made on a statistically supportable basis between point sampling locations for a gas plant, between different gas plants, and from year to year.

(9) That monitoring stations for ground level concentrations should have the capability to record the levels of sulphurous gases in the atmosphere on a continuous basis.

(10) That all plants be required to upgrade their in-plant, on-site and off-site monitoring systems to the level of the best available in the industry at any given time.

(11) That government should provide a sufficient number of qualified field inspectors for both on-site and off-site inspections with authority to enter premises and make the necessary inspections. (See also sections 4.5.1.4 and 4.7)

(12) That inspectors should make their inspections at irregular intervals and give no advance notice of their intention to inspect a plant or its environs.

(13) That where more than one gas plant has to be located within a given area, adequate spacing be provided in order to avoid the additive effect of their effluents.

4.4 SOUR GAS FIELD OPERATIONS

Exploration prior to discovery uses much the same methods for sour gas as for oil or sweet gas, as the composition of the deposit is yet to be determined. The extra hazards associated with the discovery of and production from sour gas wells are recognized by industry and additional precautions are taken because of the toxic properties and the corrosive capabilities of the material. Water, whether salt or fresh, in the raw gas greatly facilitates corrosion by hydrogen sulphide and as a result corrosion inhibitors must be metered into the gas stream at the wellhead.

In dealing with very sour wells employees are required to work in pairs and to have emergency equipment available in their truck at all times. Some operations in addition maintain regular radio checks between the plant office and field personnel.

Recent Energy Resources Conservation Board regulations require that safety shutdown valves be installed in the tubing of sour gas wells. These must be located at least 100 feet below the surface and automatically shut off the tubing in the event of uncontrolled flow rates. Sour gas wells must also be equipped with low and high pressure actuated shutdown valves at the wellhead to protect the transmission line from excessive pressures and to shut in the well in the event of line failure.

Despite these precautions operations in the field at individual wells and at batteries where the feed from a number of wells are gathered and treated have effects on people, plants and animals in their environs. These are more largely associated with hydrogen sulphide whose odor can frequently be perceived in the environs. The peeling of paint and the corrosion of wire fences have been common occurrences. Hydrogen sulphide is the active agent in these cases though sulphur dioxide is also corrosive but through different chemical reactions and yielding a different chemical product from the corrosion of the wire.

Two general questions were posed: is the land owner sufficiently protected in his surface rights against development by the holder of the mineral rights in the particular case of sour gas with its attendant problems.

Secondly, are the rights of public at large sufficiently well protected against the development of mineral rights on crown lands or on privately held lands in the particular case of sour gas wells and batteries.

RECOMMENDATIONS

(1) That additional protection in right of entry procedures be provided by statute to private landowners in respect of the development of sour gas deposits on their land above that provided for sweet gas or oil wells.

(2) That the additional disbenefits sour gas fields impose on a larger public than the landowner become a base for stricter site selection guidelines than are practiced for sweet gas or oil wells.

(3) That compensation for disbenefits derived from sour gas wells and batteries be assigned to the citizens who suffer them and that these become a recognized part of the costs of operating the sour gas industry. (See also section 4.7.)

4.4.1 Wells and Pipelines

Problems can arise at well sites and in pipelines because of excessive pressure, corrosion and mechanical interference. The loss of sour gas to the environment for any of these reasons can create a hazard.

Industry has adopted systematic and well-thought-out programs to control and minimize the incidence of such occurrences. As time passes, however, even under best contemporary practice the possibility of leaks at joints or ruptures in pipelines increases.

Because of the corrosive nature of the sour gas and because of its toxicity when released, particular concern is to be associated with pipelines that have carried sour gas from the fields to the plants for many years.

As corrosion cannot be completely controlled and continues with the passage of time, the chances that a pipeline may spring a leak accumulate with the years.

RECOMMENDATIONS

(1) That the sensitivity of leak detectors be improved and frequency of leak detection surveys be increased for sour gas pipelines in a stepwise fashion as the line ages, and at intervals presented by local experience.

(2) That industry and government jointly estimate the life over which a pipeline may be expected to retain safe performance under specified operating conditions and that a practice of replacing active sour gas pipelines at these calculated times be adopted, unless cause can be shown that in any particular case no risk to safety exists.

4.4.2 Field Flaring

Field flares are maintained as a safety mechanism in the operation of sour gas transmission systems. Regulations require these flares to be kept burning for the purposes of safety in depressurizing or in upsets within the system. Regulations also require that they be kept burning continuously with sweet natural gas as the fuel. Sour gas is then added intermittently as circumstances require. In the past many fields had a flare at each well. Now a large number of fields have been unitized by leading their wells into a single common flare. When sour gas is fed to the flare the odour of hydrogen sulphide can often be detected in the area. This is an indication that the hydrogen sulphide has not been completely burnt while passing through the flare. As well, flares have been known to be extinguished under certain conditions and without automatic re-ignition systems, to discharge uncombusted sour gas to the atmosphere.

RECOMMENDATIONS

(1) That the further unitization of the flare systems of sour gas fields be encouraged in order to keep the number of flare stacks to a minimum.
(2) That the technology of flame lighting and maintaining the flame in flare stacks be improved to prevent flame burnout.
(3) That reliable automatic re-ignition systems be a requirement of all stack systems.

(4) That improvements be made in the design of flare stacks in order to achieve improved combustion efficiency under all operating conditions and minimize the incidence of flame-out, and that they be monitored regularly to ascertain that combustion is complete.

(5) That improved surveillance methods be instituted for flare stacks operating at well and battery sites or other remote locations so that abnormalities can be promptly detected by the responsible party.

(6) That adequate, all-weather access roads or other access devices be installed to provide quick access for maintenance personnel and equipment to all flare stacks.

4.5 LIVING SYSTEMS

Of the several topics discussed at the public hearings the one which received the most attention was the interaction between gas plant emissions and living systems. To be included in living systems are humans, animals and vegetation. That the sour gas plant emissions have had an effect on living systems is known from the history of areas in which several of them are located.

There has been a tendency in the past to ignore the effects of emissions on humans and animals, and to concentrate on their effects on vegetation and inanimate objects such as fence wire and farm machinery in the vicinity of sour gas plants. A general stand taken in the past by industry and by government has been that there had been no damage to the health of humans or animals from this cause. For these and other reasons there is often insufficient information about how living systems are in fact affected by these effluents. Some suggestions will therefore be made in this section as to where additional research would be helpful. It should be noted that some members of the sour gas industry in Alberta have recently taken the lead in initiating these kinds of research programs. Some general recommendations follow.

RECOMMENDATIONS

(1) That a comprehensive environmental survey be made by government in representative districts as determined by climate, terrain and geography over the area of potential impact of existing or of proposed sour gas plants. These surveys are to include the status of vegetation and soils as well as of human and animal populations in the typical areas.

(2) That following the first survey both for new and for established sour gas plants environmental surveys of the same area be repeated about once every five years.

(3) That the comparative environmental surveys recommended above be used as a component in decisions leading to site selection for new sulphur plants or expansions of old ones.

4.5.1 Human Health

The history of citizen-industry interaction is much different for the sour gas segment of the gas industry than for that wherein only sweet gas plants are operating. There is also no doubt that some people have suffered health damage, including fatalities, due to the operation of sour gas plants. The regulations set in the past to guide the industry have not provided full protection for the entire population. The situation at present is not as serious as in the past but affected citizens still believe they are suffering ill effects from sour gas plant emissions.

The setting of standards for individual pollutants has not been based on a thorough knowledge of the effects these pollutants actually have on people in Alberta. In addition, by not examining the situation in depth, there is a tendency to dismiss effects on the health of individuals and to attribute a person's actions to psychological states or even to a desire to gain a monetary recompense. No serious attention seems to have been paid to the long-term effects of low level exposure, to possible synergistic effects that may occur when several pollutants are present, to the sensitization of individuals or to the special sensitivities that different individuals, age groups or sexes might display. Indeed it might well be recognized that an individual's psychological state is also a real and factual reaction to a set of circumstances.

If a person is affected in some way by factors he knows to be harmful and can get no redress, consequences are bound to follow. One remarkable feature of the hearings was that though highly qualified professionals and scientists volunteered thoroughly researched and clinical opinions on the health of animals, the health of green plants, the health of forests and streams and even the health of the weather, no professionally qualified person appeared to give clinical or research data on the health of humans.

There is a distinct advantage in ensuring that the health of people is not damaged in the first place, but then if people do feel they are being harmed the situation should be investigated immediately and remedial action taken.

RECOMMENDATIONS

(1) That medical research in the Province including the Faculties of Medicine of the Universities devote some attention to typical unique health problems indigenous to the Province, such as the short-and long-term effects on the health of humans of the various emissions from sulphur extraction gas plants.

(2) That clinical records and evidence as to the health history of individuals exposed to these conditions be gathered and studied from the past and continue to be collected with due regard for privacy so that case histories can be built up and made public to throw light on these disabilities in both the short and long term.

(3) That professionals in the human health field be encouraged to share their knowledge and experience on matters of environmental health for the public benefit whenever the occasion arises, as other professionals do.

4.5.1.1 Past Experiences

Of major concern when discussing the effects of gas plant emissions on humans is to determine at what point in time such effects were felt. Authority members made a particular attempt to obtain from participants at the hearings just when they felt they had been affected by the gas plants. This is especially important to determine since over the period from the late 1950's, when the first problems were experienced, to the

present, many changes have been made in the operations and control of gas plant activities. It is reasonable to state that the past was considerably more problematic than the present, yet even at present there are clearly situations which exist and must be further investigated.

Two areas of gas plant activity stand out as having been the subject of considerable controversy in the past: the Drywood Creek area south of Pincher Creek and the region in central Alberta southwest of Red Deer. In the former area, two sour gas plants were involved in a lawsuit with the ranchers of the area and this resulted in an out-of-court settlement; in the latter area there is a high concentration of gas plants which interact with an agricultural community and as a result many residents are literally surrounded in all four directions by sour gas plants. The past has not been well documented and as a result of a lack of research in the situation it has not been possible to definitely show cause and effect relationships between gas plant emissions and human health deterioration. This lack of proper investigative procedures has caused considerable hardship for those involved and created a certain degree of animosity between residents, and gas plant and government personnel.

When discussing this subject it must be recognized that not all residents of an area are affected in the same way. Indeed, the sparseness of the population living near gas plants, in combination with the topographical and meterological conditions dictates that some residents will be in contact with emissions a much greater percentage of the time. When studying the effects on individuals, therefore, it is necessary that these conditions be understood and that also factors such as the difference in susceptibility of individuals be taken into account. Nothing can be gained by making strong recommendations concerning past occurrences for the past cannot be changed. Any investigation of the past must in this respect be integrated with recommendations that will prevent similar situations arising in the future.

4.5.1.2 The Present Situation

The sour gas industry today is intensively controlled by numerous acts and regulations and the industry itself has instituted a considerable number of environmental protection measures in its operations. Plant emissions are more heavily monitored and better instrumentation reliability permits smoother operation and fewer upsets in plant activities. Notwithstanding this fact, the public hearings heard evidence of individuals still feeling that emissions from these sour gas plants were presently affecting their well-being. It may well be that some of the present experiences of individuals that have been affected over a long period of time are due to past conditions which have essentially sensitized them to these pollutants. If this is the case, then some people may come to be affected by pollutant levels which are harmless to the great majority of the population.

The public hearings in themselves have not answered the question as to what the present situation is in actuality. Two sides of the issue were heard, that of the industry and that of individuals who believe that they have been affected by the sour gas plants. On the one hand, industry stated that there have not been any effects on human health as a result of their operations, and they based this view on the belief that current ambient air quality standards are sufficient to protect the health of individuals. On the other hand, submissions from individuals residing in the vicinity of gas plants were very strong in their allegations that they have been and are being affected by gas plant emissions. Again it must be remembered that not all sour gas plants are necessarily implicated in this situation, for some individuals did state that to the best of their knowledge they had not themselves been affected by plant operations. Until an intensive investigation of the situation is undertaken, it will not be possible to definitely determine in detail the impact of these sour gas plants on the huma population.

4.5.1.3 Future Prospects

The effect of gas plant operations on humans is not expected to be as prominent in the future as it has been in the past. Present and future regulations will hopefully serve to better protect the health of humans. Most new sour gas plants will probably be built in areas of sparse human population. This is not to say that existing gas plants will not continue to have some impact on humans or that there will not be any interaction when plants are built in and around human settlements. The future will certainly have its problems, and we must attempt to define and present these problems before they occur. Long-term effects of low level concentration of pollutants must be more carefully considered in the future. The tendency in the past has been to place more emphasis on short-term high concentrations. Furthermore, a unique opportunity exists here to study the effects of principally one pollutant in a relatively clean atmosphere as well as the synergistic effects of two or more identifiable pollutants as compared to most other studies reported to date where research in the field has been undertaken in the much more complex urban environment. Future developments including the tar sands will see large processing plants built with attendant sulphur removing facilities. If these plants are located near population centres there will certainly be an interaction between their emissions and the human population. This subject is to be dealt with in the section on site selection.

RECOMMENDATIONS

(1) That a well balanced research program which looks at the human element as affected by sour gas plants be undertaken. In order to provide a basis of comparison,control groups from areas around sweet gas plants and from areas in no way affected by gas plant emissions should also be included. Short-and long-term effects of exposure to low and high concentrations of relevant pollutants should be included as one aspect of the study.

(2) That the investigative team carrying out this human health and semi-sociological research project be gathered from outside industry and government personnel. The team should be multi-disciplinary, have access to all past records, and be funded both by government and industry.

(3) That prior to sulphur extraction plant construction and operation a thorough investigation of the human situation be carried out with attention also given to long-term effects of low level pollution concentrations. This should be repeated periodically during the lifetime of the sour gas plant.

(4) That suitable planning procedures including public hearings be invoked to assure that human needs will be given expression when new sulphur extraction plants are located or old ones expanded.

4.5.1.4 The In-Plant Situation

An area of major concern, particularly to employees, was the disparity between the conditions which exist within a plant and those prescribed for the outside.

In the case of both sulphur dioxide and hydrogen sulphide the levels which have been accepted by the industry for continuous eight hours a day, five days a week exposure, are very far in excess of both the odor detection levels and the ambient standards for outside air. Further, the monitoring that is applied within the plant is much less intensive than that required by regulations for outside.

In addition, workers in the plants are continually subjected to abnormally high noise levels, and in certain plant areas these can exceed the limits of safety even for short exposure.

Records of the Workmen's Compensation Board in the past five and one half years attribute 337 reported accidents and 15 fatalities to hydrogen sulphide. The feeling on the part of the Alberta Federation of Labour was that such conditions were unreasonable and could not be justified for the workers if they were considered unacceptable for the general population.

Relevant Recommendations, including a proposed joint management-labour health and safety committee appear in section 4.7, under the heading, The Identification and Assessment of Environmental Damage. Other recommendations follow.

RECOMMENDATIONS

(1) That the objective of industrial health regulations be the prevention of damage to the health of the worker and hence a reduction of the need for compensation.

(2) That the Industrial Health Services Division be so strengthened as to enable it to field three teams, one located in Edmonton, one in Calgary, and one in Lethbridge. This would require the addition of four people to the present staff.

(3) That any changes in working hours at sour gas plants to longer continuous periods, as for example to achieve a shorter work week, be subject to approval by the Provincial Board of Health. (Alberta Regulation 298/72, September, 1972.)

(4) That exposure to noise levels in and around gas plants should be the subject of careful evaluation by the Industrial Health Services Division of the Alberta Department of Health and Social Development.

(5) That standards reflecting lower concentrations of toxic gases in sulphur extraction gas plants be considered and subjected to regular review with due attention paid to the effects of long-term exposure to low concentrations as well as short-term exposures to high concentrations and that in-plant safety regulations be redrafted accordingly.

(6) That no employee be in any way disadvantaged by his employer if the employee seeks to improve health, safety or job training practices in his place of employment or seeks to bring to light shortcomings in them or disadvantages he or others might have suffered from them.

(7) That a certification program in Occupational Health, at the postgraduate level, be offered by a faculty of medicine of an Alberta University.

(8) That a certification program in Industrial Hygiene be offered by an Institute of Technology with a view to training Industrial Hygiene inspectors for the western provinces.

4.5.2 The Health of Animals

Like human beings, animals both domestic and wild are subject to adverse effects from pollutants in the air that they must breathe. The wide proliferation of gas plants in the rural areas of Alberta results in maximum exposure of animals of all kinds to the effluents from these plants. Wild animals and birds may move away from an accustomed area if atmospheric conditions become unpleasant for them, but domestic animals do not have this mobility and aquatic fish life must persist as best it can in the accustomed streams even under conditions that threaten its very existence. The hearings were told of many instances of respiratory distress in farm animals, and there are documented instances of fatal effects from toxic lubricating fluids finding their way into watering holes used by cattle. The extent to which wild animals have suffered from sour gas plant effluents is not well known. It must be assumed,however, that at least some restriction of their range could have resulted and that this would in turn have had its effect on their populations.

In addition to the direct effects that sulphur extraction gas plant effluent might have on the health of animals, the possibility was voiced that rather specific indirect effects have also occurred. These are discussed in section 4.5.4, under the heading Selenium Deficiency Diseases. A discussion of the direct effects follows.

4.5.2.1 Domestic Animals

The location of sulphur extraction gas plants in some of the prime agricultural areas of Alberta has given rise to a situation somewhat similar to that discussed with respect to human interactions. Throughout the southern part of the province many herds of domestic animals co-exist with gas plants. In the northwestern part of the province the area is mostly forested and there is little interaction between the domestic animals and the gas plants. While animals may breathe the same air as humans, they also have access to waters which flow from gas plants and to storage pits into which toxic chemicals are poured as a result of plant operations.

The industrial submissions presented to the hearings admitted no health damage suffered by domestic animals at present ambient air quality standards. In contrast to this, several individuals related instances where they believed that an animal's physical debilitation could be attribtued to either gaseous emissions or the ingestion of liquid effluents. Most cases that were mentioned related to respiratory afflictions. Unfortunately, the accounts of individual farmers are not looked upon by some as being scientific and are therefore generally discounted by those who prefer to have what they consider to be a more professional basis upon which to make statements. This is hard to justify as the farmer is a professional observer of livestock and vegetation. In any event without further investigation of this situation there are no grounds to state in effect that no health damage has been suffered by animals. While the information relating emissions to respiratory ailments may be somewhat informal, there are authenticated cases where domestic animals have ingested liquid effluents and have as a result been affected.

As with humans there may only be a fraction of the total domestic animal population residing near gas plants that will be affected. It is common to see animals grazing up to plant boundaries,which would indicate that in these instances no visible or immediate harmful effects have been noted. There is,however, also the question of possible long-

term effects on the animals and as a result the effect on the economics of farm management. If pollutants affect the productivity of domestic animals, then this may be viewed not only as a direct effect on the animal but as an economic disbenefit to the farmer. This is one of the externalities that must be considered when reviewing the overall environmental effects of sour gas plant operations.

4.5.2.2 Fish and Wildlife

Although the effects of sulphur extraction gas plants on humans and domestic animals have received some attention from researchers and legislators, there seems to have been less concern for wild animals. Aside from the interest in wild species for conservation reasons, certain advantages may accrue by using them as biological indicators. Wild animals, like domestic species, are sensitive to many effluents from gas plants and changes in their behaviour and population density may be related to pollution levels.

The use of bioassy techniques has become commonly accepted in many monitoring procedures and should become an important aspect of monitoring the effluents of sulphur extraction gas plants. In addition to the use of particular organisms for testing the toxicity of plant effluents, it may be possible to identify indicator species. Research may show, for example, that some indigenous species are highly sensitive to sulphur dioxide fu and changes in their abundance or behaviour may be a forewarning of gradual changes to the natural ecosystem.

The main point to be made is that much can be gained by detailed studies of the natural environment in relation to the effects of industrial effluents. By combining these studies with the technical and physical aspects of pollution monitoring we are more apt to develop solutions which are meaningful biologically as well as technically. In cases where toxic materials are permitted to enter a watercourse in lethal amounts the entire fish population may be killed for a variable distance downstream

depending upon the dilution and stability of the toxicant. When a watercourse is subjected to continuous addition of sub-lethal concentrations the species composition and density of the fish population may change as a result of one species having different physiological tolerance levels. As the original species emigrates or fails to reproduce it is replaced by more hardy species. On the other hand, the toxicant may alter the amount and composition of the available food with consequent changes in the fish population. These alterations may result in a population of sport fish being replaced by less desirable species in terms of recreational or commercial fishing.

Most wild animals, and birds in particular, are very territorial in their habits and many species may spend their entire lives, and in fact may have lived for many generations, in close proximity to sulphur extraction gas plants. They can therefore sustain effects over very long periods and even transmit some effects from one generation to another generation. Careful study of these populations, in comparison with populations not so exposed might provide some insight into the long-term effects of chronic exposure to pollutants.

Large ungulates, both browsers and grazers, may concentrate particular toxic compounds after consuming contaminated foliage. Comparative physiological studies between wild and domestic species may reveal differences in the assimilation of toxicants as a result of dietary or behavioural differences. In particular, a continuing study of birds may reveal effects on reproductive processes that might take a longer period of time to show up in larger animals with longer life spans.

Recommendations relevant to the health of animals appear in some later sections; as for example in environmental surveys and in monitoring and control. Some additional recommendations follow.

RECOMMENDATIONS

(1) That comprehensive research programs into the effects on animal health and productivity of the operation of sulphur

extraction gas plants be undertaken at least by government.

(2) That company and government monitoring procedures include a periodic check on the status of indigenous wildlife species in the vicinity of the plants.

(3) That local residents be encouraged to report any noticeable effects on domestic and wildlife species in the area of sulphur extraction gas plants.

(4) That standard monitoring procedures which have been recommended before include regular sampling of water for quality tests and an analysis of aquatic organisms above and below the plant or field site.

(5) That careful consideration be given to potential impact on groundwater and surface drainage systems in locating new gas plants, and that this should be included in the Environmental Impact Statement prepared when the plant is proposed.

4.5.3 Vegetation

It has been known for some time that green plants in general are sensitive to gaseous pollutants. It also became apparent from information presented at the hearings that the effects of sulphurous emissions, especially sulphur dioxide, have been researched to a considerable extent. These investigations have been prompted as a result of widespread mortality of vegetation in the vicinity of many polluting industrial complexes in various parts of the world.

During the hearings numerous references were made to smelter operations and power plants in other areas of Canada and in the United States which had virtually eliminated plant life over large areas primarily as a result of excessive sulphurous emissions. While these examples underlined the potentially destructive nature of sulphur compounds it was argued that they had little relevance to the Alberta situation because present emission standards prevent such toxic concentrations from entering the atmosphere. There was also disagreement concerning the applicability to Alberta of research results from other areas with major differences in climate, soils and plant species.

It is one thing to show that sulphur dioxide has deleterious effects on plants under controlled experimental conditions and apparently quite another to recognize the symptoms of sulphur dioxide poisoning under field conditions. This is particularly the case for chronic, low level exposures similar to those which may occur in connection with some gas plants in Alberta. In the first place, different plant species vary in their sensitivity to particular pollutants. Secondly, the response of a given species to a particular concentration depends upon the age of the plants, their general vigor, and the stage in the growing season, as well as previous and concomitant exposures to other pollutants or environmental stresses. Even when the effects of these other factors are understood it may still require an expert to unequivocally relate damage to a particular pollutant on the basis of a short-term survey. Presumably studies of longer duration would be required to show whether a plant was reacting to the accumulative effects of chronic low-level exposures or intermittant high concentrations.

Because of their ubiquitousness growing plants offer the best opportunity as indicator species for pollution. As primary producers of energy in the natural food chain they are the logical focus for research efforts. If we can learn to recognize the early stages of plant damage from such sources as sour gas plants we may be able to forestall more serious effects on dependent organisms throughout the natural system. Such an understanding of plant responses to toxic effluents will be helped by studies and surveys included as regular components of a continuing monitoring program.

RECOMMENDATIONS

(1) That industry and government cooperate to develop a bioassay monitoring system which would incorporate a plant species, or combination of species, with high sensitivity to sulphurous emissions.

(2) That regular vegetation damage surveys be conducted by government in order to relate environmental impact with recorded

emission levels and atmospheric conditions.

(3) That maps showing the relative degrees of damage to vegetation be prepared and used as guidelines for the placement of mobile monitoring facilities.

4.5.3.1 Crops

Given the importance of agriculture to the economy of Alberta and the increasing demands on the productive capacity of the land we can ill afford to ignore possible adverse effects on crops resulting from the operation of sulphur extraction gas plants. The fact that plants require a certain amount of sulphur for normal growth makes it imperative that we are aware of the limits between beneficial and harmful sulphur depositions.

Plants may continue to live within their tolerance for particular toxicants although their overall vigour may be affected. For agricultural crops this could mean a decrease in productivity with resulting economic effects. In addition to decreases in biomass the nutritional qualities of the crops could be adversely effected.

Consideration should also be given to investigating possible synergistic reactions between sulphur effluents and other widely dispersed chemical compounds such as pesticides and fertilizers. These interactions are normally complex and would require the research efforts from a number of disciplines to document the facts in detail.

Presumably data exist in government or industry files on production rates for various crops throughout the Province. A detailed examination of these records to compare production in areas close to gas plants with more distant areas may provide some gross indication of the nature and extent of the problem. A true understanding, however, of the relationship between emissions from gas plants and the quantity and quality of agricultural crops will require comprehensive field studies.

RECOMMENDATIONS

(1) That government and industry undertake comprehensive studies on the effects of sulphurous emissions on agricultural crops commonly grown in Alberta. Adequate funding should be available to ensure the continuation of such studies for a period of time sufficient to evaluate the effects of changing weather patterns and seasonal influences.
(2) That studies be initiated to determine if there are nutritional differences in crops related to emissions from sulphur extraction gas plants.
(3) That researchers solicit the aid of residents in the area of gas plants in determining the most suitable locations for experimental field studies.

4.5.3.2 Trees and Forests

There are a number of sulphur extraction gas plants in Alberta which are located in forested areas of the Province. Although there may be less direct effects on humans due to relatively sparse populations, there is no reason to assume that the total environmental impact is any less than for agricultural areas. Natural forests are more diverse and complex than the plant associations maintained by monoculture farming practices, and are therefore more stable as ecological systems. There are, nevertheless, individual forest species which are susceptible to damage from relatively low concentrations of gaseous pollutants such as sulphur dioxide.

Research agencies such as the Canadian Forestry Service have conducted studies on the effects of sulphurous emissions from gas plants on forest species. A co-operative research effort between companies operating in the Whitecourt area of the Province was also described during the hearings. This type of activity should be encouraged and possibly supplemented by Provincial Government efforts and funding.

As with crop species, attention should be given to possible deleterious effects on wood quality as well as plant productivity. In general, external forces which alter normal tree growth affect the quality of wood fibre and may decrease its value for lumber or pulp. It is also important to recognize that forests are more than trees. Associated plant species including herbaceous ground cover, even lichens, play an important role in the forest ecosystem and must be considered in any attempt to study the effect of industrial pollutants.

RECOMMENDATIONS

(1) That monitoring systems for gas plant effluents in forested areas of the Province be comprehensive and well organized even though the human population may be meagre.
(2) That fish and wildlife officers, forest rangers and other government personnel who frequent the forested areas of the Province be trained to recognize the effects of sulphur emissions on major forest species and report thereon.

4.5.4 Selenium Deficiency Diseases

A proposal about an indirect effect of sulphur emissions was heard at the hearings. It had to do with the occurrence of selenium deficiency diseases in domestic animals.

In western Alberta, particularly in the environs of the sulphur extraction gas plants from Pincher Creek to as far north as Whitecourt, there has been a relatively high incidence of selenium deficiency diseases in domestic animals. Selenium is essential as a nutrient for animals and lack of a proper supply can lead to severe debilitation of the animal. Many farmers and some veterinarians in western Alberta attribute the rise in the incidence of White Muscle Disease to emissions from sour gas plants. It is known that elements which are similar to each other can replace each other in chemical reactions both within and outside of living systems.

The element most similar to sulphur is selenium. In view of this the Authority commissioned a staff report on the proposed relationship of selenium deficiency diseases to ambient sulphur concentrations in the area. The report appears in the summary of the hearings. Information relevant to the problem is also to be found in two reports from the Canadian Forestry Service on the effects of sulphur dioxide on vegetation which also appears in the Summary.

Both sulphur and selenium are critical elements in the life support processes of many plants and animals. Sulphur is an essential element in plant metabolism and in many structural components of plants. Sulphur is found in the vitamins thiamine and biotin. It is also an important constituent of all proteins, structural as well as metabolic, and is part of the molecular structure of the amino acid, cystein, cystine and methionine. It is known that selenium can substitute for sulphur in sulphur amino acid and protein synthesis. Several pertinent facts can be cited.

4.5.4.1 The Repression of Selenium Uptake by Sulphur

The repression of selenium uptake by sulphur is apparently well known. Research studies have shown that the presence of sulphate in the soil represses the uptake of selenium by cereal crops like wheat and by forage crops like alfalfa. The more sulphate present, the more the uptake of selenium is restricted, and this is true, according to Hurd-Karrer in the paper "Relation of Sulphate to Selenium Absorption by Plants", whether the selenium, as selenate, is present in great or small concentrations. This author suggests that the "occurrence of the selenium in wheat grain in intimate association with the proteins and the sulphur-containing amino acids might be the result of substitution in these compounds."

Most studies have been done in selenium rich soils. In selenium-poor soils, the further possibility arises that selenium perhaps in the form of a selenate should be added to the fertilizer applied to the fields particularly if sulphate is being added, either in the fertilizer or indirectly through the air.

4.5.4.2 The Identification of Artifically Introduced Sulphur Compounds

Sulphur compounds introduced artifically into the immediate environment surrounding the sulphur extraction gas plants are predominantly hydrogen sulphide and sulphur dioxide together with elementary sulphur dust. At a greater remove oxidation has changed the state of these compounds to sulphur trioxide, sulphuric acid, and ultimately to neutral sulphates.

4.5.4.3 Sulphur Uptake by Plants

It is well known that plants can absorb sulphur dioxide and hydrogen sulphide through their leaves or needles. In the case of sulphur dioxide this occurs without damage at low concentrations, with some damage at modest concentrations but without detriment to the overall growth of the plant, and with fully toxic effects at higher concentrations.

Plants can also absorb sulphur from the soil in the form of sulphates. Various sulphates are well-known fertilizers and promote plant growth in well-understood ways. There are, of course, upper limits to the concentrations at which sulphate is helpful to the plant, but as mentioned before the element sulphur is essential to plant growth and the plant can take it up either from the air in the form of sulphurous gases or from the ground in the form of sulphates dissolved in the water.

4.5.4.4 Selenium Compounds

Selenium is a much less common element than sulphur. It is taken

up by plants through the root system although it may not be necessary to the metabolism of the plant itself. It is known, however, that when sulphur is deficient green plants can use selenium to substitute for sulphur in sulphur amino acid and protein synthesis (Sulphur Dioxide and Forest Vegetation, Canadian Forestry Service Information Report, NOR x 49, December, 1972)

4.5.4.5 Sulphur and Selenium Effects on Animal Life

Sulphur is a necessary element for both plants and animals but because of its relative abundance and its widespread use as a fertilizer in sulphur-deficient areas, humans as well as the lower animals generally get enough of it for their needs. Selenium presents quite a different problem. In the first place, it is a relatively rare element. Secondly, it is apparently not essential that plants have it, even though plants can incorporate it into their systems and in some cases even concentrate it to a level that makes it poisonous to animals.

Animals on the other hand, do need it but in the right amounts. Either too little selenium or too much selenium can produce serious malfunctioning in animals. In Alberta the problems have been associated with selenium deficiency diseases particularly among grass-eating animals.

4.5.4.6 Natural Levels of Sulphur and Selenium around the Sulphur Extraction Gas Plants

As circumstance would have it, both sulphur and selenium are naturally low in concentration in the soils in the general vicinity of most if not all of the sulphur extraction gas plants in Alberta. A history of selenium deficiency diseases has been recorded in these areas, sometimes almost on an epidemic basis, but, it was claimed, only since the onset of the operation of the sulphur extraction gas plants. There is informal evidence supporting this claim, but since veterarians do not report their findings to the

Department of Agriculture, definitive statistical data have not yet been associated.

4.5.4.7 The Relationship between the Sulphur Extraction Gas Plant and Selenium Deficiency Diseases

Sulphur dioxide and hydrogen sulphide, injected into the air by the sulphur extraction gas plants, are both taken up by green plants in the vicinity. What then happens to the plant in the Albertan environment is not yet well known. The question, however, arises: when the plant absorbs the sulphur dioxide and hydrogen sulphide that have been artifically injected into the air, will the overall selenium/sulphur ratio in the plant as a whole be adversely affected?

To pose the problem in its simplest form, it is known that selenium can replace sulphur in sulphur amino acid and protein synthesis in green plants. It is also known that selenium and sulphur can both be taken up by the plant through its root system, even though in these areas in Alberta both these elements are naturally in low abundance. Will, therefore, the opportunity afforded the plant to absorb sulphur compounds from the air through its leaves act so as to reduce the selenium content in the plant as a whole compared with what it would have been if there had been no sulphur compounds in the atmosphere?

The sulphur compounds in the atmosphere are eventually oxidized and are taken to earth as sulphates. In this form, particularly in sulphur - deficient soils, they act beneficially to plants increasing their rate of growth. Indeed, if sulphates are added to the soils as fertilizers in areas in the vicinity of the sulphur extraction gas plants, the soil is still sufficiently sulphur deficient that the sulphate acts as a positive growth stimulant. The work of the Department of Agriculture has shown that in these cases the percentage of selenium in the plant does decrease. It is suggested that in this case the reduction in selenium content comes about from a dilution effect; that is, the sulphate fertilizer has made the plant grow more rapidly so that, although it has taken up the same

amount of selenium in the same time, it has taken up less selenium for the same amount of growth.

4.5.5 Antidotes to Selenium Deficiency Diseases

If untreated, selenium deficiency diseases can have quite undesirable effects on domestic animals, since they affect fertility, produce still-births and White Muscle Disease and reduce the rate at which flesh is put onto beef cattle. However, the artificial addition of selenium to domestic animals by routine procedures which farmers can adopt is not too difficult nor too expensive. Selenium injections, selenium-enriched salt licks, and other methods can be employed. The addition of selenium as selenate to the fertilizer program might under sutiable controls, be a preferred method.

The further question as to how wildlife might be protected against selenium deficiency diseases still remains.

RECOMMENDATIONS

(1) That studies be undertaken to determine the radial distribution of sulphur emissions from sour gas plants and their effects on the productivity of vegetation, including an analysis of the selenium content in the vegetation within the study area.

(2) That veterinarians be required to report the details of all cases of White Muscle Disease or other selenium deficiency diseases to the Department of Agriculture so that proper statistics on incidence and distribution can be accumulated.

(3) That studies be undertaken to determine the selenium concentrations and the sulphur/selenium ratios in soils in which selenium uptake by plants might be seriously repressed by the artificial addition of sulphur compounds, particularly when such soils are already deficient in

selenium and sulphur.

(4) That a study be made of the effect that sulphur dioxide and hydrogen sulphide absorbed from the air through the leaves might have on the selenium content of cereal and forage crops.

(5) That research already begun on the effect of sulphate fertilizers on selenium uptake be continued.

(6) That studies be undertaken as to the desirability and the means, including chemical state and concentration, of adding selenium to selenium-deficient soils exposed to artificial sulphur fertilization.

(7) That further studies be conducted into procedures to treat selenium deficiency diseases in animals, both domestic and wild, and that routine methods which can be followed and can be programmed by farmers and stockmen be worked out and made available to all.

(8) That since selenium deficiency diseases are widespread in the vicinity of sulphur extraction gas plants, such remedial measures as are now available be made known to the farmers so that they can protect themselves in the most direct and economical way known against these hazards.

(9) That government carry out studies to determine the incidence of selenium deficiency diseases in wild animals.

4.5.6 Research Requirements

A mechanism is needed to ensure adequate examination of research requirements concerning the environmental effects of sulphur gas plants. Continuing dialogue between Government and industry is required, as well as a process for the review and funding of research programs. As

well the extent and costs of the environmental effects of sulphur gas plants should constitute an accepted part of Government monitoring programs for sulphur gas plant operations.

RECOMMENDATIONS

(1) That research programs be funded by a means which will ensure a continuing flow of information to industry and Government alike.

(2) That environmental research into sulphur gas problems receive funding from industry, from Government at the federal and provincial levels, and from the Alberta Environmental Research Trust.

(3) That all gas plant environmental research papers be placed in the library of the Alberta Department of the Environment, in order to ensure complete availability to industry.

(4) That continuing discussions be held between the Government and industry, through the Alberta Industry-Government Sour Gas Environmental Committee, to ensure complete continuity of the monitoring of environmental problems in the sour gas industry.

4.6 ECONOMIC CONSIDERATIONS

Much discussion centered on the economics of sulphur extraction. In addition to the conventional economics relating to the marketing of sulphur and of natural gas, considerable attention was given to the costs to industry of environmental controls and the costs of environmental damage claimed to be caused by sulphur gas plants but borne by others. There was general agreement that the polluters should pay, which in essence means that the producer picks up the costs and then passes them on to the consumer. There was rather less agreement as to whether the polluter was paying all of the costs or as to what mechanisms might enable the principle to be completely fulfilled.

Some arguments will be developed towards general recommendations in what follows. More detailed recommendations that elaborate on the general recommendations are reserved for section 7.7, entitled The Identification and Assessment of Environmental Damage.

4.6.1 The Economics of Sulphur Extraction

In 1971 the Energy Resources Conservation Board issued directives to the sour gas industry which stated that sulphur recovery efficiencies should be improved. The Board, which is required by law to see that energy resources are recovered to the maximum extent possible, based its decision for these proposed higher recoveries on current technology and the cost of the facilities required to achieve them. The reaction of industry as expressed to the Authority was that increased recovery efficiencies were not justified by present economics and that some sulphur extraction plants would appeal for exemptions from them. Specific objections had to do with the capital costs that tail gas cleanup might require to meet the new guidelines.

The earlier guidelines given to industry had been calculated on the basis of the percentage of sulphur that could be profitably recovered.

As time passed, and technology improved, new guidelines were set as additional increments of sulphur became profitably recoverable.

In the guidelines now before the industry, the Energy Resources Conservation Board adopted an integrated approach, rather than an incremental approach, to the economics of sulphur recovery. These new guidelines express the sulphur recovery efficiency that can be profitably obtained consideringthe whole sulphur extraction process, rather than just the last incremental portion of it. Old plants, it was suggested by some operators would be harder pressed by this changed approach than new plants yet to be built.

In its calculations the Board assumed a contemporary price for the sulphur and a moderate profit to the company in its operations. It did not include recompense for any environmental effects outside the plant. The change in the basis of calculation from an incremental to an integrated approach did, however, permit higher recoveries to be rationalized and consequently environmental damage to be, by implication, diminished. The point to be made, however, is that the new guidelines presently before industry but not necessarily yet met by them, are based on a calculation in which the sulphur is to be extracted at a reasonable although modest profit, but with no provision for defraying the costs of any environmental damage that may occur outside the plant site.

4.6.2 The Price of Natural Gas

Many sulphur recovery facilities came into production in the mid-1960's when the price of sulphur was rising. It reached a high of about $35 a long ton in 1968. At this price, recovery and marketing were attractive. In the last few years, however, the market for sulphur has been less satisfactory and prices below $10 a long ton have been seen and some stockpiling has taken place. The price of the other product of the sour gas plants, sweet natural gas, has also been exposed to change.

The Energy Resources Conservation Board has continued its analysis of the economics of the natural gas industry in hearings that have been given considerable attention. The conclusion of the Board was that natural gas was being sold below its true market value in comparison with other energy fuels. The Board recommended that the market value of natural gas should increase by from 10 to 26 cents per thousand cubic feet. This range of increase could double the value of the product. Though not necessarily ignored, the costs of environmental effects were not part of the calculation.

4.6.3 The Costs of Environmental Controls

The costs of environmental controls are borne by industry as a regular part of overall operational costs. No estimate of the costs of environmental controls was given, nor to what extent their use was over and above normal processing requirements. The industry claims that the standards it is required to meet are sufficiently rigorous to prevent any damage to the environment, and that it therefore is already bearing the full costs of environmental damage through the costs of the measures it undertakes to meet the standards. Others claim that environmental damage from the sour gas plants has occurred and is occurring but that these costs are not borne by industry. The Canadian Petroleum Association recommends that "more complex analysis of ground level concentration is recommended where unique topographical or meteorological features exist" but that "present methods are adequate for relatively flat terrain and normal meteorological conditions."

4.6.4 The Costs of Environmental Damage

There can be no real doubt that the operation of sulphur extraction gas plants has been a disbenefit to some individuals. There is at the same time equally no doubt that the operation of the sour gas industry has been a positive benefit to many individuals, to the public treasury, and of course, to the shareholders and employees of the operating companies

themselves. To the extent that a contribution to public revenue is a contribution to all the citizens of the Province, it can be argued that those individuals who have suffered disbenefits may also have been compensated by experiencing some of the benefits of the operation of the industry. The question, however, is to what extent, if any, and through what mecanism should they receive further compensation in order to make their situation equal to those who have enjoyed similar benefits without suffering any of the disbenefits.

4.6.4.1 The Nature of the Disbenefit

Some of the effects on the environment of the operation of sulphur extraction gas plants are known beyond a reasonable doubt. Some are probable but not proven. Others are implied but may be less probable. Some may be positive or negative irritants or even subjective elements in the sensor. Many may vary from individual to individual among both the plant and animal kingdoms. There is as well in every case, since standards have changed in the past and are projects to do so again in the future, the question as to the time the disbenefit occurred.

Tied in with it is the additional question that if a particular disbenefit took place in the past, will subsequent effects follow from it now and in the future? Finally, there is the subtle but inescapable judgement as to what constitutes an improper invasion of the rights of a man.

Can a man expect in justice that his property, his farm, his home, be kept free and safe from the effects of the actions of others who do not own or are not on his land? Must he accept a dollar value to be placed on his discomfort or has he a right to claim himself legally free and safe from such encroachments upon his property and his home by others? Is there an irreconcilable conflict between what might be justice to an individual and what might be in the public benefit? No doubt some such conflicts can be resolved by money payments, but is there a point at which such a solution becomes unacceptable?

4.6.4.2 Effects on the Physical Environment

There is no doubt that sulphurous compounds in the atmosphere can corrode and cause chemical change to occur in physical entities such as wire, paint, electrical connections, cutlery, silverware, etc. Hydrogen sulphide gas and sulphur dioxide gas act differently on these materials but there has been no evidence yet given to indicate the action of these gases in any way improves quality or performance of these objects. It is an unambiguous case. In the past a few settlements have been worked out with farmers based upon factors like the length of wire fencing the farmer had, the exposure of painted buildings and the distance from the contaminating source. These settlements were, however, made without committal by companies and on this basis were settled out of court.

Though there is no reasonable doubt that damage of this sort has occurred in the past in Alberta near and particularly downwind from sulphur extraction gas plants and flare stacks, it may be open to question whether such damage is still occurring now or if it will continue to occur after stricter guidelines and emission control standards are imposed.

There is the further question as to whether all sulphur extraction gas plants are still causing this damage, or if some still do, or if none do. More precisely perhaps the open question is the rate at which these chemical reactions are now occurring. Undoubtedly since the rates of chemical reactions of this sort depend directly upon the concentrations of the reacting species, the amount of damage in a given time becomes less as the concentrations of the sulphurous materials decrease.

It is, however, doubtful on chemical grounds whether the reactions are altogether eliminated unless and until at least one of the reacting species is totally removed. In that case what is a tolerable limit? Should a farmer be given monetary compensation in appropriate sums if his barbed wire and his paint last only half as long, 80% as

long, 90% as long, 95% as long or 99% as long as they would if these artificial and corrosive agents were not present in the air touching upon his property; and if so, how does one assess the life of his property in these terms and hence the cost of the damage?

4.6.4.3 Environmental Effects on Green Plants

Two separate situations must be considered. Are the green plants in the public domain, or are they domestic crops grown in support of a private individual's livelihood? The details of the reactions of green plants to sulphurous fumes in the air and sulphurous materials in the soil and water are discussed elsewhere. It is as always, necessary to distinguish between past effects and the present.

Under the proposed guidelines there is reason to be optimistic that little permanent damage may be done to the forests, or to the yields of most of the forage and cereal crops that most of the farmers raise in these areas. The damage that is done is often local, subject to remedial measures, due to a temporary upset or of the sort that green plants can recover from without loss in yield unless it is perhaps particularly sensitive to sulphur dioxide in which case the yield may be affected by some percentage points.

Even if the yield is not affected, or not affected much, there is still the question as to whether the selenium content within the forage or cereal crop has been affected and if so, whether this can contribute to selenium deficiency diseases in animals.

Again, the question of compensation comes up. Is a farmer entitled to compensation for a loss in yield due to a pollutant? If so, how can it be shown what the loss in yield was and what the cause of that loss in yield was?

The extensive damage to plant growth that sulphur dioxide has been known to cause in other parts of Canada in past and present times is not now occurring in Alberta. If there is damage in the public domain it would then be a disbenefit to any citizen who felt aggrieved by the

sight of it. The evidence is that the damage to green plants on crown property is for the most part minor and repairs itself within a year or two. This question should, however, be considered open to further enquiry.

4.6.4.4 Effects on Animals

There is a great deal of evidence that the health of domestic animals has been affected by the introduction of the sulphur extraction gas plants into the Province. This is a serious question, all the more so since some of the areas in which the gas plants operate are important meat-producing areas, and this industry is important both to the individuals engaged in it and to the Province as a whole.

This matter has been discussed in greater detail in other parts of this report. The problem here is how the individual who owns the animals can be affected. Again, one must distinguish between the past and the present. If the health of basic herds has been affected through fertility rates and stillbirths, cattlemen will have suffered a disadvantage of one sort. If the rate at which the herd puts on weight is affected, but the rate at which the herd multiplies is not, the cattlemen will be affected in another way. However both would lead to cost disbenefits to the owner.

If a medical remedy to these disbenefits can be found and applied so that no ill effect is suffered by the domestic flocks and herds, then three problems arise: Who is responsible for the losses of the past? Who is responsible for the costs of the remedial program? What measures must now be taken to assure that the present remedial programs are fair, safe, and in the public benefit?

4.6.4.5 Human Health

The case for health effects in domestic animals may rest to an important degree on a selenium deficiency base. The problem of human health

is quite different. There seems to be no question of selenium deficiency diseases in the human population in Alberta. There is, however, considerable evidence of other health impairments in individuals claimed to have arisen from the operations of sulphur extraction gas plants and varying in intensity with the age and sex of the individual as well as with other health parameters the individual may possess.

There are in addition clear enough indications that reactions to hydrogen sulphide, mercaptans and sulphur dioxide which in some individuals are merely irritants or nauseous experineces, in others become health impairments and emotional problems.

There are complex questions here. There is no doubt that prevailing winds, terrain phenomena and inversion effects can expose humans to incompletely dispersed plumes that contain unusually high concentrations of sulphurous compounds, and they do so for from very short periods up to longish periods of time but then usually at rather lower concentrations.

People know when they are sick, and they often know what it is that has made them ill, particularly if it is an exposure to something that has a smell or a taste, or can be seen. Sometimes the thought of it alone is enough to induce a melancholy feeling if not worse. Moreover, if children are exposed to it in their younger years, will it somehow affect what might happen to them many years later? Or, if an older person perhaps with relevant health imperfections is exposed to the conditions will his life span be unnecessarily shortened?

If compensation is involved how are the several ills and health and emotional problems to be sorted out so that costs can be assessed? What case can be made and what proof can be given as to the source of the ailment? Upon whom does the burden of proof lie? The nature of the disbenefit may be plain enough but on what basis can compensation be devised for health impairment and health hazards?

4.6.4.6 Nuisances and Hazards

There is no doubt that sulphur extraction gas plants smell. They may smell worse some days than others or point their smells in different directions from day to day, and over greater or lesser distances. It may be true that, as the saying goes, "If you can smell it it won't hurt you, but if you can't smell it you're dead." It may even be that with long exposure the smell becomes agreeable and forms a pleasant memory as seems to have been the case with the barnyard odors of the past.

It is, however, also true that though the stuff that smells bad is bad, other stuff that may be present that hardly smells at all is also bad. Hydrogen sulphide smells worse but is present in less concentration, whereas sulphur dioxide, though a much less powerful odiferous agent, is the main ingredient causing discomfort and damage.

The question then as to when what may only be an irritant is to be classified instead as a positive health hazard seems always somewhat open, particularly in the vicinity of the plants themselves, and then particularly in areas that can be further defined using prevailing winds, terrain, inversion conditions, etc. What is fair compensation to the user of the surface under these circumstances as against the person or the company who is exploiting the subsurface resources that may underlie it?

4.6.4.7 Man as Man and Man as Producer

The argument clearly makes a distinction between man in his two capacities. A man can use his property to live on it. He can also use it to gain his livelihood from it. In one capacity environmental disbenefits impinge on him as a producer. The problem of compensation is simple in the second case, but difficult in the first.

As a producer, whether it be of livestock, of forage crops, of chickens or eggs, the effect on his productivity can in principle be calculated and costed. The disbenefit may be assessed against the source,

which is another producer. The conflicts between producers can be settled by equitable compensation calculated in fair and simple terms.

When a man suffers a disbenefit in the quality of his life, however, and in thecomfort of his home, justice may be more difficult to find. Shall that which gives rise to his discomfort be terminated? If it is terminated, might it not give rise to discomfort to other men, through unemployment and other disbenefits? Is it fair to ask the man to move and to compensate him for moving? Will money itself suffice to satisfy the man for such a dislocation?

4.6.4.8 The Timing of the Disbenefit

There is no doubt that individuals have suffered disbenefits in the past. There is doubt as to which disbenefits can be proven and which cannot. The questions remains as to the nature of the disbenefits now being suffered, or what may be suffered in the future. It is necessary and important to close the book on the disbenefits of the past as quickly as possible.

Compensation should be paid for present disbenefits, and for those that continue into the future. However, the principle must also be recognized that an individual has the right to the free and gainful occupation of his own house and property and that this right exists apart from the marketplace.

A third requirement must be met by regulation and by site selection. If environmental damage still persists, mechanisms are needed to identify, prove and assess environmental damage so that compensation can be awarded as required. A General Recommendation is included hereunder. Specific recommendations are included in section 4.7 under the heading The Identification and Assessment of Environmental Damage.

RECOMMENDATION

1. That compensation be paid by operating companies for environmental disbenefits if any, arising from the operations of sulphur extraction gas plants after all regulations have been met.
   In doing this the following guidelines are suggested:
   a) That an estimate be made of the extent and money value of what might be called "Compensable Damages" and these are to be charged against the source and passed on to the consumer who is ultimately reponsible for bearing them.
   b) That the public benefit be maintained so that a balance between the needs of all citizens is established in any of the conflicts between different resource users.
   c) That the basic right, beyond price, of each man in his house, his property and his province, to have pure air, pure water, and unpolluted land be guaranteed him by regulations, to the maximum possible practical extent.
   d) That recommendation 1.c) be met by regulations and by site selection, and that if environmental damage still persists, mechanisms to identify, prove and assess environmental damage and machinery to award compensation be set up. Specific recommendations follow in section 4.7 under the heading The Identification and Assessment of Environmental Damage.

4.7 THE IDENTIFICATION AND ASSESSMENT OF ENVIRONMENTAL DAMAGE

4.7.1 The Prevention of Environmental Damage

The Authority is convinced that prevention is the preferred method in respect of potential environmental damage from the operation of sulphur extraction gas plants. A system of regulations and enforcement, reviewed at regular intervals through public hearings as recommended in section 4.3 under the heading Monitoring and Control and in particular recommendation (5) under section 4.3.3.2 is undoubtedly the soundest way to achieve that objective.

There is, however, substantial evidence to indicate that regulations have not prevented all environmental damage in the past and are not preventing it in the present. There is also good reason to believe that standards, for the most part simply borrowed from other countries that have quite different parameters and problems, lack a worked-out correlation with indigenous circumstances. Finally, even when standards thought most suitable to a particular region are devised, it is possible that prevention may not yet be perfect, and that some environmental damage may still occur because of accidents, plant upset, unexpected meteorological or terrain effects and other factors.

In brief, mechanisms for the identification and assessment of environmental damage seem to be required both to provide evidence on which the most suitable preventative regulations can be based, and also to discover whether, with any given set of regulations, environmental damage is still occurring.

RECOMMENDATIONS

(1) That a two-step approach be adopted towards the prevention of environmental damage. The first step will consist of regulations and enforcement at the level best suited to the overall public benefit. The second step will consist of a system for identifying and assessing any environmental

damage that may then still occur.

(2) That standards and enforcement be re-examined at regular three-year intervals through public hearings.

4.7.1.1 Site Selection and Plant Expansions

According to the evidence an important element in the prevention of environmental damage is the selection of sites for new plants or for the expansion of established facilities. The factors that make site selection important have been discussed at length in earlier sections. They include the requirement to avoid or to minimize impacts on human populations and other living systems, to escape from meteorological, terrain or other geographical circumstances that can put otherwise sound environmental practices to hazard, and to reconcile the conflicts that can arise between different users of the same or related resources, or of unrelated resources in the same geographical district.

RECOMMENDATIONS

(1) That environmental impact statements accompany proposals for new sour gas plant construction or for the expansion of existing facilities.

(2) That the environmental impact statements be comprehensive and include the elements referred to in the recommendations contained in this report. The impact statement should also show why the proposed site is considered to be preferable to other possible sites.

(3) That public hearings be held on the environmental effects of proposed new sour gas plants and of substantial expansions to established facilities. The environmental impact statement should be made available to the public prior to the hearings, and the hearings should be held by an agency of government

that has environmental responsibilities but does not have administrative or regulatory responsibilities for sulphur extraction plants.

4.7.2 The Provision of Reasonable Proof of Environmental Damage

After all reasonable steps have been taken to prevent environmental damage, it is possible that some disbenefits may still occur. In these circumstances the objectives of any program designed to assess environmental damage should be threefold.

(1) It is necessary to determine whether or not damage has resulted from the operation of the sulphur extraction gas plants.

(2) It is necessary to determine what has been damaged.

(3) It is necessary to determine what the costs of this damage have been to those who have borne it.

Two quite distinct situations present themselves; although the main principles are the same in each case, namely, the polluter must pay, the public must be protected, there must be proof of damage, and industry must not bear an unfair burden. The two situations are: (1) the situation relating to individuals outside the sour gas plant, and (2) the situation relating to individuals inside the sour gas plant.

These principles require that both the sour gas plants that may have caused the damage, and specific elements from among the public who may have experienced the damage, should participate on equitable terms in any proposed program for the identification and assessment of environmental damage.

4.7.2.1 The Input from Industry

Many of the sulphur extraction gas plants or groups of them working together have already developed research and evaluation programs aimed at determining whether or not there are environmental effects which can be associated with the operation of their plants. These are most commendable

efforts and have a practical objective in mind. The sour gas plants stand in the role of the agency from which the damage presumably is coming. A major responsibility to determine if there is damage, what that damage is and who is affected by it therefore naturally rests on their shoulders.

4.7.2.2 The Sectors of the Public Who Are Affected by Environmental Damage

Those individuals whose lives or livelihoods may be damaged by the operations of sulphur extraction gas plants clearly have a basic interest and a right to participate in deciding what might be construed as environmental damage, the specific kinds of damage that should be investigated, the methods selected to determine whether or not environmental damage has resulted, and the assessment leading to the determination of what the cost of that environmental damage has been to themselves. These elements of the public may be individual citizens, farmers or ranchers, other industrial operators, private families, employees of the sour gas plant, etc. They are the ones who suffer the ill effects of any environmental damage that the plant may produce and consequently should be involved in its determination.

4.7.2.3 Input from Government

Ideally government at local, provincial and federal levels represents a disinterested position between the principal protagonists, namely the entity from whence the damage may emanate and the entity that receives the damage. Government, however, also has the responsibility to prescribe the limits within which industrial activities can be allowed to proceed. It must therefore supervise and monitor the compliance of industry with its regulations and continually strive to keep these regulations fully compatible with the public good.

4.7.3 The Identification and Assessment of Environmental Damage

The hearings clearly developed the point that environmental damage may occur even when the laws and regulations of government are being met. The question then arises, if the regulations are being satisfied and damage still occurs, who is then responsible? This possibility has less novelty after reflection, and poses a smaller problem if relevant historical developments are recalled, as, for example, the emergence of workmen's compensation.

Industry operates under certain regulations but accidents may still occur. If they do certain actions follow. The principle would then be plain. The person who suffers disbenefits can receive compensation after due process of identification, assessment and proof through a system set up by government to which affected citizens have ready access. Such a system will be proposed to handle compensation for environmental damage. It is true that in some cases environmental damage may occur that does not create a cost problem for a specific individual, or if so, the problem of assigning compensation to an individual is difficult. Problems relating to the effects of effluents on wildlife and on property in the title of the Crown are examples. It is suggested that even in cases of this sort, the system that will be proposed should be assigned some responsibility for determining whether or not damage has occurred and the extent of that damage.

In other cases where environmental damage is claimed or may be shown to have affected the health and the livelihood of specific individuals or of groups, it is then suggested that every effort be made to clarify the facts of the case and to determine the cost factors involved.

The question of who pays may seem somewhat irrelevant since it is ultimately the citizen who pays by way of higher taxes or higher prices for the product. Yet there is a need to establish what externalities are to be considered as part of industrial operations. In this respect an industry must be held responsible for its effects on the environment: these are results of operational procedures and preventing or determining

them must be assumed to be a part of the overall cost of running a plant. The operational cost of the machinery set up by Government might, however, be better borne by Government.

In proposing systems for the identification and assessment of environmental damage, maximum use will be made of existing organizations and of precedents already established in the province. This is perhaps somewhat easier to do for in-plant situations, although a basically similar system will be proposed for environmental damage outside the plant.

RECOMMENDATIONS

(1) That Joint Committees be established to assess environmental damage, advise on its prevention and cure, and estimate its costs.
(2) That membership on these committees be jointly from plant management and from the affected part of the public.
(3) That these Joint Committees have access to appropriate government agencies.
(4) That unsettled claims for compensation be referred to appropriate crown corporations, with statutory authority to award compensation for proven claims.
(5) That citizens be enabled to introduce complaints on environmental damage suffered by the Crown for consideration both by the Joint Committees and by government agencies.

4.7.3.1 Inside the Plant

By far the most important environmental problem within the sour gas plants is the health and safety of the people who work there.

The primary responsibility of any program to assess environmental damage is clearly to prevent such damage from occurring. Inside the sour gas plant the health and safety of the employees and the job training related to these objectives are of primary concern in setting up preventative measures. Ambient air standards within the plant, attention to proper

plant procedures and the development of and adherence to proper regulations and practices related to health and safety fall within this primary responsibility.

The secondary responsibility is the actual identification of any environmental damage that may have occurred, despite preventative measures, and the initiation of suitable steps to resolve or compensate for the damage.

Programs like this have had a successful history in the Province through the Workmen's Compensation Board and the Division of Industrial Health Services of the Department of Health and Social Welfare. The Authority is aware that some organizational changes are being considered within government in respect of its own operations in this regard. The Authority is also aware of the successful operation of joint labour, management, Health and Safety Committees in some industries in the Province.

The Authority wishes to emphasize again that in its view, the primary emphasis should be on prevention. Inside the plant this requires the cooperation of labor and management, good job training practices related to health and safety, and strong support from Government in the areas of industrial health and of health and safety inspections. The recommendations follow.

RECOMMENDATIONS

(1) That joint labor-management committees on Health, Safety and Job Training be established in each sour gas plant, chaired by a representative of management and with a representative from labor as a co-chairman.

(2) That the joint committee study and make recommendations on health, safety and job training so as to prevent health and safety problems from arising.

(3) That management from time to time retain independent qualified experts to investigate health, safety and job training conditions in the sour gas plant and

report to the joint committee.

(4) That the joint committee review complaints as to health, safety and job training practices in the sour gas plant, including incidents and accidents, and make recommendations to management and to labor for corrective action, and where necessary report to the Workmen's Compensation Board and/or other appropriate government agencies.

(5) That membership on the joint committee be evenly divided between labor and management, and report to management through the chairman, and to labor through the co-chairman.

(6) That the members representing management be appointed by management and the members representing labor be appointed by labor.

(7) That some strengthening and reorganization among government departments and agencies be considered including the following:

(a) That the Division of Industrial Health Services be strengthened, as previously recommended. (Section 4.5.1.4.)

(b) That the inspection branch of the Workmen's Compensation Board be strengthened so that it can assume sole responsibility for the health and safety inspections of sulphur extraction plants and of related plant operating procedures and that reports on any health and safety aspects of working conditions should be made by Board staff independent of inputs by company or union personnel or the personnel of any other government departments or agencies.

(c) That a Division of Health, Safety and On-Site Job Training be created within the Department of Labor.

(d) That the objectives of the new Division of Health, Safety and On-Site Job Training be primarily preventative in nature.

(e) That the strengthened Division of Industrial Health Services be transferred from the Department of Health

and Social Development to the proposed Division of Health, Safety and On-Site Job Training in the Department of Labor.

(f) That the strengthened health and safety inspection staff, including the Health and Safety Inspectors, be transferred from The Workmen's Compensation Board to the proposed Division of Health Safety and On-Site Job Training in the Department of Labour.

(g) That the services of the Health and Safety Inspectors be made available to The Workmen's Compensation Board, though the staff be administratively within the Department of Labor.

(8) That if the proposed Division is established in the Department of Labor, safety inspections of sulphur extraction gas plants and of plant operating procedures be a regular responsibility of this Division, and that this be done out of its own resources.

(9) That any member of the joint labor-management committee on Health, Safety and Job Training have access to the Division of Health, Safety and On-Site Job Training through the chairman of the joint committee, or through the co-chairman after notification of the chairman.

(10) That claims for compensation when they arise continue to be processed and judged by the Workmen's Compensation Board.

(11) That no individual suffer a disadvantage in job security, promotion, pay or in any other way, if he draws attention to deficiencies in health or safety conditions or on-site job training practices, but instead be encouraged to do so through the method of special awards or merit mention for good suggestions.

4.7.3.2 Outside the Sour Gas Plants

Although systems to protect the health and safety of workers and

to award compensation for disabilities received while on the job are now routine even though they need improvement, systems have not yet been devised within this province to give similar protection including compensation to individuals who suffer disbenefits outside the plant. Such a system will be proposed.

It is proposed that the primary aim of the system be the prevention of environmental damage. The system should also include mechanisms whereby such environmental damage as might still occur can be identified and assessed, claims judged and compensation awarded when justified.

It is thought necessary and appropriate that both the entity who may have received the damage as well as the entity who may have occasioned the damage have adequate representation in the system.

There are several precedents on which the proposed system is based. Among these are the research programs sponsored by single sulphur gas plants or groups of plants into the environmental effects of their operations. The Authority was told that a public presence on these research groups would be welcomed.

Other major precedents have been cited in the previous section, including the recommendations.

RECOMMENDATIONS

(1) That the efforts of the industry to prove out, identify and assess such environmental damage as may arise from the operation of sulphur extraction gas plants be done under the direction of a joint committee.

(2) That membership in the joint committee be equally drawn from the management of the sour gas plants and from residents in the environs of the sour gas plants with a representative from management as chairman, and a representative from the public as co-chairman.

(3) That, if possible, a joint committee be formed for each sour gas field, but failing that, a joint committee be

formed for each sulphur extraction gas plant.

(4) That the membership of the joint committee be appointed as follows:

(a) The representatives of the sulphur extraction gas plants by the management of the sulphur extraction gas plants.

(b) The representatives of the public by elected bodies at the most appropriate local levels, i.e. by municipal or town councils or by District Planning Commissions, depending on the boundaries of the area affected.

(5) That cooperative connections be set up between joint committees to avoid unnecessary repetition or duplication of work.

(6) That the costs of the joint committees and of the work undertaken at their direction be borne by industry.

(7) That the joint committees report directly to management, to the local elected bodies, and to government, and that these reports be in the public domain.

(8) That part of the objective of the joint committee be the prevention of environmental damage and that this be partly through the provision of information to the public hearings that are to regularly review air, water and soil quality standards.

(9) That part of the objective of the Joint Committee be the identification and assessment of environmental damage and the determination and assignment of its cost.

(10) That the joint committees study and make recommendations on the health and safety of humans, plants and animals in the environs and on how they can be protected from environmental damage.

(11) That the joint committee review complaints as to environmental damage claimants might have suffered, including health or other ill effects to humans, plants and animals, and make recommendations to management and to the public for corrective action, and where necessary report to

appropriate government agencies.

(12) That the joint committees receive, review and assess complaints from citizens as to environmental damage the Crown might have suffered, in respect of Crown lands or undomesticated plants or animals.

(13) That some strengthening and reorganization within government be undertaken as follows:

(a) That a Division of Environmental Health be established within the Environmental Protection Service of the Department of the Environment.

(b) That the primary objective of the Division of Environmental Health be the prevention of environmental damage, but that another principal task will be to inspect, identify and prove such damage as does occur, and to assist with cost assessments.

(c) That any members of a Joint Committee named in this section will have access to the Division on Environmental Health through the chairman of the Joint Committee or through its co-chairman after notification of the chairman.

(d) That the Division of Environmental Health have field inspectors and a staff of professionals including ecologists and economists, but also use staff inputs from the other Divisions in the Environmental Protection Service, and from other Services in the Department of the Environment, and maintain as close a liaison as is necessary with other departments respresented on the Natural Resources Coordinating Council as well as the Departments of Health and Social Development, the Department of Advanced Education and the Department of Culture, Youth and Recreation.

(e) That where claims for compensation for environmental damage arise and are not settled within the joint

mittee that a statute provide they may be brought before an agency of the government with environmental responsibilities but no administrative or regulatory responsibilities.

(f) That if this agency be the Environment Conservation Authority, a Committee on the Environmental Compensation be established within the Authority for this task.

(14) That the systems proposed here, if established, be reviewed through public hearings at an appropriate time, preferably when the first regular review on emission standards is called for.

5. CONCLUSION

In concluding this report the Authority wishes once more to express its appreciation for the time and effort contributed by so many people towards the hearings.

All submissions, verbal or written, and including those received subsequent to the hearings, have been studied and the concerns of the authors carefully noted.

The Authority feels that the recommendations contained herein, reflect those concerns and now wishes respectfully, to submit them.

ENVIRONMENT CONSERVATION AUTHORITY

W R Trist

Chairman

Vice-Chairman

Member

Member up to February 28, 1973.

6. APPENDICES

APPENDIX - 1

LISTING OF RECOMMENDATIONS, OBSERVATIONS, CONCERNS EXPRESSED AT THE PUBLIC HEARINGS

Briefs presented at the public hearings contained many points which indicate the scope of environmental effects of sulphur extraction gas plants. To outline the main points, a tabulation has been made of those mentioned in three or more briefs. The various parties making the submissions have been indicated as Industry (I), individuals (P), associations and groups (A), governmental bodies (G). Briefs presented were: I-17; P-21; A-16; G-7. It should be noted that the comprehensive submission by the CPA on behalf of the industry is included with (1) in the present tabulation.

Recommendations, observations and concerns indicated in three or more briefs.

Recommendations

	I	P	A	G
present standards are adequate	8			
revise tolerence levels; set more stringent standards		6	3	2
control emissions by ambient air quality standards	9			
more extensive monitoring; include other pollutants		2	2	
use biological indicators (i.e., lichens) for pollution detection		1	2	1
oppose tail gas cleanup as present standards adequate	5			
clarify roles of DoE and ERCB	5	1		
require more research into environmental effects	1	4	4	2
industry, government and people co-operate on research projects	6	1		
companies must prove no environmental damage has or will be done		2	1	

Observations on Environmental Effects

	I	P	A	G
little or no environmental damage has occurred	6	1	1	2
yes, general environmental damage has occurred		1	3	1
human health has been affected		14	1	1
no evidence of damage to health	3			
physician believes health problems due to air pollution		3		
livestock health has been affected		12	2	1
evidence of damage to vegetation (the industry agrees there has been slight damage)	8	8	3	2
physical damage (corrosion, rust, paint)		12	2	3
odour is noticed		10	4	2
water pollution has occurred (one industry brief said there has been none)		1	1	1
situation has improved (one person said it was worse)		5		1
sulphur dust on property	3	2		
believe yellow in rain puddles was S dust, officially told it was pollen		3		1
no problem before plants built		3		
smoke evident		4		
sulphur is beneficial to soil	2		1	
the company accepts its corporate responsibility	4			
good plant-community relationships	3	1		2
conducting research into biological effects (on vegetation)	6			
research into weathering, rusting, etc	3			
reclaiming soil	3			
few or no complaints	4	1		2
operations beneficial (roads, employment, etc.)	4		1	
design equations are conservative	3			

Concerns

	I	P	A	G
pollution control is not economical (refers mainly to tail gas cleanup)	6			
legal recourse is inadequate		7	1	
lack of government co-operation		3	2	1
credibility of government is questioned		1	1	1
atmospheric conditions may hinder monitoring and control		1	1	1
sulphur plants contribute to selenium deficiency		3		
industry doesn't co-operate with people		3		

Recommendations, observations, and concerns stated by one or two briefs.

Recommendations

Present standards are too low (1); sample pollutants at point of discharge (P,G); set standards by lack of environmental damage (1); allow guidelines to apply to plants on an individual basis (1); regulating agencies should take stronger diciplinary action (P,A); do more research on emission equations (1); government sponser research (1); companies responsible for research (A); research by independent agents (P): make research results available to public (I); let public know what is happening (I); more soil sampling (P); improve S transportation method to prevent dust (G); involve workers in environmental matters (A); protect workers legally from reprisal in reporting (A); upgrade training; enforcement, inspections (A); safety record good (I), not good (A); be concerned about tar Sands (P,A).

3.2 Observations on Environmental Effects

Animal health has not been affected (I); no evidence of physical damage (paint deterioration, etc.)(I); workers have been affected by H_2S, noise, (A); considerable flaring (P); little flaring (I); property value in vicinity of plants has decreased (P,G); property value has increased (I); plant sites are visual pollutors (P,A); individuals have complained to plants (P); no research has been done on the effects of gas plants on people (P); not certain of pollutants (P); co-operate with other plants (I), (indirectly plants co-operate through the Whitecourt Environmental Study Group and the Alberta Sulphur Research Limited); plant does not consult with the community (I,G); research is being done on plant process (I); plant is not doing any research (I); plant tests chemicals with a fish bioassay (I); have applied for exemption from guidelines (I); can meet guidelines without tail gas cleanup (I); will install tail gas cleanup (I); plant answers complaints (I); flaring is necessary (I); workers are (are not) involved in environmental protection (I(I)); safety meetings are held between workers and administration (I); little evidence workers affected by threshold limit value for gases (G); design equations are acceptable (CPA)(I), not acceptable in the location of a particular plant (I); plant exceeds standards on occasion (I).

3.3 Concerns

Ambient standards vary across Canada (I); increased S recovery not an environmentally sound practise (I); worker safety and lack of safety training (A); tolerence levels uncertain (I); monitoring not sensitive enough (I,P); cost to the individual in proving damage (P); regulations not adequately enforced (P); people have become sensitized to pollutants (P); problems occur with plant upsets (P); value system not just (P,A); plant has a problem relating complaints to plant records (I); government testing program can be questioned (A); experts don't see problems (P); long term effects of S on soil (P,A); government interference with Klemm report (P,A); the report was not written by an interdiciplinary committee (P,A).

APPENDIX - 2

BIBLIOGRAPHY

1. W.R. MacDonald and R.F. Klemm. Selenium Animal Health and Sour Gas Plants - Environment Conservation Authority Staff Report. January, 1973.

2. R.F. Klemm. Environmental Effects of the Operation of Sulphur Extraction Gas Plants. Situation Report for Environment Conservation Authority Public Hearings.

3. A.A. Loman, R.A. Blavel and D. Hocking. Sulphur Dioxide and Forest Vegetation. Northern Forest Research Centre Information Report NOR-X-49. December, 1972.

4. Canadian Petroleum Association. Submission to the Environment Conservation Authority on Environmental Effects of the Operation of Sulphur Extraction Gas Plants. September, 1972.

5. Environment Conservation Authority. Terms of Reference for Public Hearings - Environmental Effects of the Operation of Sulphur Extraction Gas Plants.

6. Environment Conservation Authority. A Prospectus for Public Hearings. Environmental Effects of the Operation of Sulphur Extraction Gas Plants.

7. Environment Conservation Authority. Environmental Effects of the Operation of Sulphur Extraction Gas Plants. Proceedings of the Public Hearings. October, 1972. Parts I, II, and III.

8. Environment Conservation Authority. Environmental Effects of the Operation of Sulphur Extraction Gas Plants. Summary of the Public Hearings. May, 1973.

BIBLIOGRAPHY (con't)

9. Stanley Associates Engineering Limited. Environmental Effects of Sulphur Extraction Gas Plants in Alberta. Public Opinion Survey.

APPENDIX - 3

ENVIRONMENT CONSERVATION AUTHORITY

LIST OF PUBLICATIONS

Environment Conservation Authority. Brochure. Revised edition. 1972.

Environment Conservation Act, 1970 being chapter 36 of the Statutes of Alberta, 1970, with amendments up to June 2, 1972, including pertinent sections of other acts referring to the Environment Conservation Authority. Office Compilation. 10 pages.

Annual Report

Environment Conservation Authority. First annual report, November 1970 to November 1971. April, 1972. 101 pages.

Environment Conservation Authority. Second annual report, December 1971 to December 1972. March, 1973.

Environment Conservation Authority. Four Ways Forward: education, management, economics, legislation, 1972. 27 pages.

PUBLIC HEARINGS

Public Hearings on a Proposal to Restore Water Levels in Cooking and Hastings Lakes, August 23, 25, 1971

E.P.E.C. Consulting Ltd. An economic analysis of the Cooking and Hastings Lakes. June 10, 1971.

Macroplan Consultants Ltd. Recreation potential and development feasibility in Halfmoon, Hastings and Cooking Lakes. July - August, 1971.

Prospectus: Cooking and Hastings Lakes public hearings, Edmonton and South Cooking Lake, Alberta, August 23, 25, 1971. 8 pages.

Proceedings: public hearings on a proposal to restore water levels in Cooking and Hastings Lakes, August, 1971. 1 v.

Summary: public hearings on a proposal to restore water levels in Cooking and Hastings Lakes, August, 1971. 64 pages.

Report and Recommendations: public hearings on a proposal to restore water levels in Cooking and Hastings Lakes, August, 1971. (When available)

Public Hearings on the Environmental Impact of Surface Mining in Alberta December 13, 15, 17, 21, 1971 and January 6, 1972

F.F. Slaney and Co. Environmental Impact of Surface Coal Mining Operations in Alberta. November, 1971. 59 pages. (Reproduced in the proceedings)

A prospectus for public hearings: the environmental impact of surface mining in Alberta, December 13, 15, 17, 21, 1971 and January 6, 1972. 6 pages.

The impact on the environment of surface mining in Alberta proceedings of the public hearings, December, 1971, January, 1972. 2 v. $4.00.

The impact on the environment of surface mining in Alberta summary of the public hearings, December, 1971, January, 1972. 205 pages.

The impact on the environment of surface mining in Alberta report and recommendations, December, 1971, January, 1972. (When available)

Public Hearings on the Conservation of Archaeological and Historical Resources in Alberta May 25, 29, June 1, 1972

A prospectus for public hearings: the conservation of historical and archaeological resources in Alberta, May 25, 29 and June 1, 1972. 7 pages.

Position paper for public hearings: the conservation of historical and archaeological resources in Alberta prepared by the Public Advisory Committee on the Conservation of Historical and Archaeological Resources. March, 1972. 8 pages. (Includes three page addendum)

Report: the conservation of historical and archaeological resources in Alberta prepared by the Public Advisory Committee on the Conservation of Historical and Archaeological Resources. March, 1972. 32 pages.

Proceedings: public hearings on the conservation of historical and archaeological resources in Alberta, May 25, 29 and June 1, 1972. 1 v. $3.00.

Summary: public hearings on the conservation of historical and archaeological resources in Alberta, May 25, 29 and June 1, 1972. 67 pages.

Report and Recommendations: public hearings on the conservation of historical and archaeological resources in Alberta, May 25, 29 and June 1, 1972. 120 pages

Public Hearings on the Environmental Effects of the Operation of Sulphur Extraction Gas Plants October 2, 5, 11, 16, 19, 1972

Klemm, R. K. Environmental effects of the operation of sulphur extraction gas plants. August, 1972. 116 pages.

Terms of reference for public hearings: environmental effects of the operation of sulphur extraction gas platns, June, 1972. 2 pages.

A prospectus for public hearings: environmental effects of the operation of sulphur extraction gas plants, October 2, 5, 11, 16 and 19, 1972. 8 pages.

Proceedings: public hearings on the environmental effects of the operation of sulphur extraction gas plants, October 2, 5, 11, 16 and 19, 1972. 1, 743 pages. $6.00.

Public Hearings on Land Use and Resource Development
in the Eastern Slopes
June - July, 1973

Information Bulletin Number 1: Terms of reference.

Information Bulletin Number 2: Current Status Report on Alberta's Eastern Slopes.

Information Bulletin Number 3: Information Centres and Source Material.

Information Bulletin Number 4: Commercial Proposals Bulletin.

Information Bulletin Number 5: Planning Statement - Oldman River Regional Planning Commission.

*Information Bulletin Number 6: Planning Statement - Calgary Regional Planning Commission.

*Information Bulletin Number 7: Planning Statement - Red Deer Regional Planning Commission.

*Information Bulletin Number 8: Planning Statement - Peace River Regional Planning Commission.

*Information Bulletin Number 9: Planning Statement - Athabasca - Yellowhead

*Information Bulletin Number 10: Foothills Land Use Concept Study.

*Information Bulletin Number 11: Task Force Position Paper.

*Information Bulletin Number 12: Science Advisory Committee Ad Hoc Committee Paper on Land Use and Resource Development in the Eastern Slopes.

*Being compiled at the time of this listing.

DR. WALTER TROST

Trost, Dr. Walter Raymond. Environmental management; presented to the Edmonton Chamber of Commerce, February 16, 1972. 11 pages.

Trost, Dr. Walter Raymond. Employment, productivity and environment; presented at the annual convention of the Alberta Federation of Labour, Calgary, Alberta, May, 1971. 11 pages.

Trost, Dr. Walter Raymond. Managing the changing environment; presented to the 1972 Annual Convention of the Canadian Institute of Management, Montreal, Quebec, June 22, 1972. 5 pages.

PUBLIC ADVISORY COMMITTEE

Public Advisory Committee on the Environment; proceedings of the first annual meetings, MacDonald Hotel, Edmonton, Alberta, November 25, 26, 1971. 125 pages.

Science Advisory Committee; first annual report, 1972. 55 pages.

Additional Studies Available

Underwood, McLellan and Associates Ltd. A preliminary assessment of environmental impact of oil and gas exploration and pipeline operations in Alberta, June, 1972. 51 pages.

E.P.E.C. Consulting Ltd. and C.L. Sibbald Agri - Business Ltd. The forest resource in Alberta: an examination with respect to Conservation, Recreation and the Forest Industry. 1972. $30.00.